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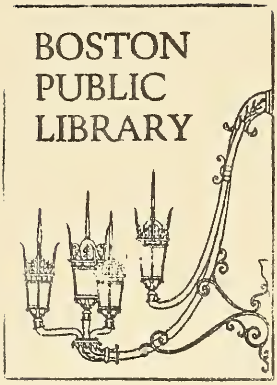

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BASIC DESIGN REPORT
INTERSTATE ROUTES 95 AND 695
BOSTON, MASSACHUSETTS

PRELIMINARY DRAFT

CLARKESON

THE CLARKESON ENGINEERING COMPANY
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APRIL 1965

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PRELIMINARY DRAFT OF

BASIC DESIGN REPORT
FOR
INTERSTATE ROUTE 95
AND
INTERSTATE ROUTE 695
IN THE CITY OF
BOSTON, MASSACHUSETTS

THE CLARKESON ENGINEERING COMPANY, Inc.

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		* Generally adaptable to all schemes
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Recommendations:

On the basis of the data assembled in plan, profile, cost estimates, effect on existing buildings and businesses in the area, the architectural treatments that can be developed in each scheme and the land uses present and planned in the area, as well as the traffic functions to be served we recommended that Scheme A, as presented on the drawings be constructed with the addition of the East Service Road in the vicinity of the Fitzgerald Expressway.

All schemes which retain the Fens as a recreational and park-like area show a total cost within 5% of each other - a percentage well within the normal accuracy of estimating at this time of design. Cost alone can not readily be the major determining factor.

Traffic service and the impact not only to the adjoining cultural and development areas but also on the hundreds of thousands of persons using this section of the expressway warrant this consideration.

The recommended scheme preserves the Fens, it services traffic the best and it provides an architectural form to preserve present cultural values and enhances areas which are apt to be redeveloped. It will seed good design for adjoining structures, public and private, which are to be erected in the redevelopment area through which this expressway goes.

From the standpoint of land takings and present structures affected in those takings, it may appear that the totally over and

under Scheme B should be selected.

In an area of diversified functions of zoning such as proposed for the roadway section an effort should be made to reduce to the minimum a potentially destructive effect of the expressway on the community.

The solution in which the roadways are wholly super-imposed on each other (Scheme B) magnifies the divisive impact of the highway in an urban area. The size and nature of the structure creates, in effect, a wall and a barrier permanently separating the neighborhoods.

The solution in which the southbound lanes are placed in cut and the northbound lanes partly overlap (Scheme A) reduces the negative impact of the highway on the neighborhood. It permits a lighter and more graceful structure above grade. It makes possible the use of land below the elevated structure and creates an architectural value and form superior to other solutions studied.

SCOPE OF PROJECT

The geographical limits of the work included in this report are that portion of Interstate Route 95 from the end of the Fitzgerald Expressway in the vicinity of Boston City Hospital and northeast of Massachusetts Avenue southwesterly about 2.0 miles to the vicinity of Jackson Square and

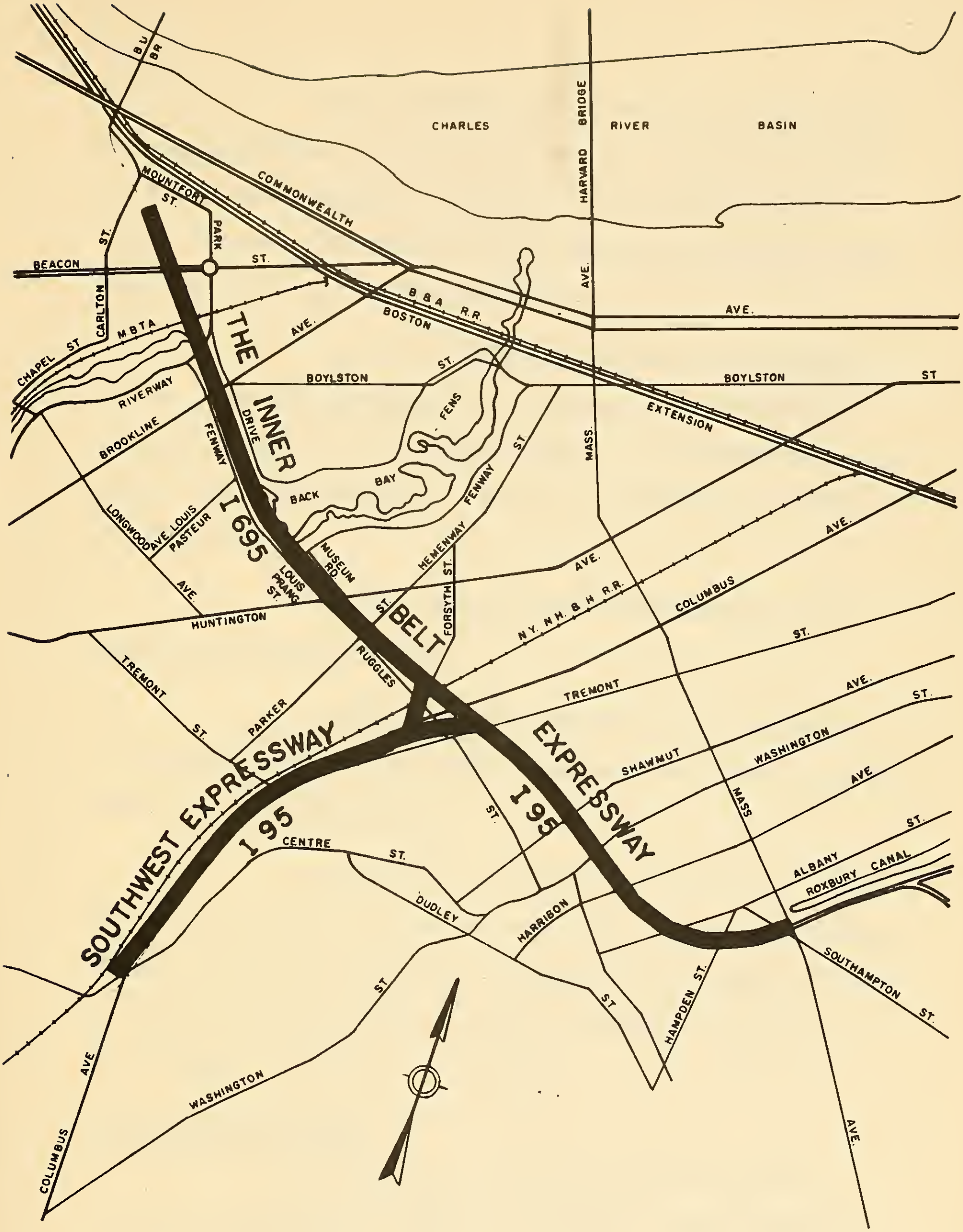
That portion of Interstate Route 695 from the Interchange with Interstate Route 95 between Shawmut Avenue and Tremont Street northwesterly about 1.5 miles to the northwest side of Beacon Street.

****

The part of Interstate Route 95 from the Fitzgerald Expressway to its Interchange with Interstate 695 in the vicinity of Tremont Street and the above described section of Interstate Route 695 constitute what has been locally called the Boston section of the "Inner Belt Expressway".

The portion of Interstate Route 95 from the Interchange near Tremont Street to Jackson Square has been locally called the "Southwest Expressway". Because of the repeated use of these local names for each of these sections of the two Interstate Routes involved, rather than their official route number designations, the reference throughout this report will be on the basis of these local names.

The general location of this study section with its Interstate numbers and local names is shown on exhibit 1.



PROJECT LOCATION MAP

EXHIBIT NO. 1

HISTORY

The location studies for these route sections had been completed before the advent of our contract. The 1962 Inner Belt and Expressway System Report established its location and principal traffic function. This location for the Inner Belt was approved by the various Federal, State and City officials.

For the Southwest Expressway and its Interchange with the Inner Belt location approval was given as far as Jackson Square by the Commonwealth's Board of Review. This approval was for a location closer to the N.Y., N.H. and H. R.R. tracks than that shown in the 1962 report.

The basic design studies reported herein are in accordance with these approvals.

This Basic Design Report is for the determination of the geometrics of roadways, center lines, profiles, ramp location and profiles and other design details.

In accordance with our contract and because of the need for corelation with the physical and cultural aspects of the areas through which these route sections traverse the firm of Campbell, Aldrich and Nulty, their staff architects and staff landscape architects, were used throughout the course of the studies.

GENERAL CONCEPTS OF DESIGN

The design of these route sections has been in accordance with the design controls for Interstate highways adopted by

the American Association of State Highway officials with such modifications as the Massachusetts Department of Public Works has indicated, within the policies of the A.A.S.H.O.

A principal modification is in regard to the vertical clearances for overhead structures to permit the transportation of oversized defense loads, a minimum 16 foot 6 inch head room clearance has been provided for all of that part of the Interstate Route 95 within the limits of this report. A minimum of 14 feet 6 inches overhead clearance has been provided for the section of Interstate Route 695 and for local street clearances.

Would we want to change the 95 & 695 designations at a future date? What effect would these clearances have?

The selected design speed for the main lines has been set at 50 m.p.h. for the determination of sight distances, vertical and horizontal alignments, acceleration and deceleration, land development and other details so effected. A design speed of 40 m.p.h. was set for the principal ramps in the Southwest Expressway Inner Belt Interchange because of the desire to avoid demolition of a major new housing project and for other right-of-way controls.

On all parts of the Interstate Routes except that part of the Inner Belt through the Southwest Expressway Interchange and the Interchange ramps four lanes of travel have been provided. The Interchange ramps are held at two lanes each and that part of the Inner Belt within the Southwest Expressway Interchange has been held to three lanes because of the drop in traffic in this area. Lane widths of 12 feet have been used throughout; 10 foot disabled-vehicle lanes have been maintained on the right hand side of each expressway section except of

course where the acceleration and deceleration lanes use this area for operational purposes. Four foot clearance lanes on the left side of the travel lanes for each direction of flow have been maintained except wherever ramps from or to the left hand side require this area for operational purposes.

The various sections demonstrating the mainline geometric controls are shown in typical sections TS-1, TS-2, TS-3, TS-4, TS-5 and TS-6.

NUMBER OF LANES

The number of lanes of travel on the mainlines are based upon the traffic values for the expressway system as established in the 1962 Inner Belt and Expressway Report.

The basic traffic figures used for these studies are those presented in the 1962 Inner Belt and Expressway System Report. They have been supplemented by 1964 City traffic cordon counts observations where available and by the traffic volume inventory of the Wilbur Smith 1963 Study where applicable.

The Inner Belt Expressway traffic projections show that it will carry in 1985 between 60,000 and 138,000 vehicles per day (two directional flow). Based upon a design hour volume of 7% of the daily average this is equal to 4600 to 8660 vehicles per design hour. For the largest of these 8 lanes or 4 in each direction are provided. Except for the Southwest Interchange area where only three lanes per direction on the Inner Belt are provided.

For the Southwest Expressway it is anticipated that the 1985 volume will average 114,000 vehicles per day, or a design hour volume of 8,000 vehicles for both directions. Four lanes in each direction are provided for this expressway.

While these volumes are somewhat below those which have been measured on many expressways, as stated in the 1962 report, these are the numbers of lanes which should be considered when viewed in context with the entire Inner Belt system and the Expressways leading to and from it. In addition the volume assignments do not represent the total demand. Restraints due to the congestion on the Fitzgerald Southeast Expressways limit, at present, the amount of traffic which can use the Inner Belt. If and when these restraints are removed these sections will require the 8 lane designs presented here.

INTERCHANGE LOCATIONS

Because of the shortness of the length of the Inner Belt the number of ramps for entering and leaving traffic must be kept to a minimum consistant with proper service to the area through which the expressway passes.

Two major Interchanges with other expressways must be provided for at the northeast end of the project in the vicinity of the Southeast Expressway Interchange. While its location is pinned down by previous construction, all movements to the Fitzgerald Expressway and the Southeast must be provided for. Since this area is also a source of considerable other traffic generation, ramps to and from the street pattern are needed for the present and future developments here.

A major interchange with the Southwest Expressway in the vicinity of the Tremont Street, Columbus Avenue, New Haven Railroad corridor must be provided.

These two interchanges limit to a great degree the location of interchanges to and from the ground level street pattern.

The Wilbur Smith arterial street traffic volume inventory indicates the capability of the various crossing street arterials to take additional ramp traffic.

Between Massachusetts Avenue and Columbus Avenue a service road pattern flanking the Inner Belt can distribute traffic to the various streets serving the areas east and west of the Belt. They now carry between 0.8 and 1.3 times their capacity and the use of a service road can provide a distributor to equalize their load.

The capacity of Tremont Street and Columbus Avenue since they have near termini both east and west of the Belt, and thus provide similar arterial functions, can handle considerably increased volumes if made alternate one-way streets. Ramp distribution to this one-way pair have therefore been considered in the various schemes studied.

Arterial service to and from the downtown area by way of the projected B.R.A. southend by-pass has also been considered in each of these studies. Its close proximity to the Tremont-Columbus Avenue corridor does not permit an additional ramp complex but does permit it to serve the ramps in this corridor crossing. Direct connecting

ramps to and from the Southwest Expressway to this by-pass are compatible with the various schemes studies and are therefore shown in the report.

To the north, Huntington Avenue is now carrying 1.2 times its rated capacity. Its proximity to the Southwest Expressway interchange further precludes its use as a ramp terminal location.

The Riverway-Park Drive arterial is limited to passenger car usage and therefore, together with its present traffic load precludes its usage as a satisfactory ramp terminal location.

The Brookline Avenue and Boylston Street arterial is presently carrying in excess of its rated capacity, and has little room for expansion due to institutional, commercial and industrial abuttors.

This practically forces the interchange to and from the ground pattern to the Beacon Street corridor. While Beacon Street is carrying close to its rated capacity, operational traffic controls can increase its capacity better than any of the others. Further, by using it for the ramp complex, damage which ramps will force on the Fens area can be reduced and distributed to Commonwealth, Brookline, Boylston and the Riverway, can be accomplished within the interchanged area, and within the limits of good traffic management.

No one pair of arterials crossed provides the ultimate in ramp termini requirements. On balance it is considered that the Beacon Street location comes nearest to providing the service required.

To accomplish this interchange it has been necessary to extend the Inner Belt study beyond the limits of Beacon Street to Eustin Street in Brookline.

The traffic pattern indicated the need for an interchange either in the Jackson Square area or between it and Roxbury Crossing. Roxbury Crossing itself is not a sufficient source of traffic to require an independent ramp complex and its proximity to the Southwest-Inner Belt Interchange precludes a ramp complex here to avoid unmanageable weaving and merging situations.

By relocating Columbus Avenue to the corridor adjacent to the railroad embankment a one-way service road on either side of the expressway can be provided by the continuance of the Tremont Street - Columbus Avenue one-way pair. The need for an interchange is indicated between Roxbury Crossing and Jackson Square to permit traffic from the Jackson Square cross streets to use the Inner Belt expressway system and to pick up arterial traffic to and from the south and the Southwest Expressway without being involved by grade crossing interference at Jackson Square.

If and when direct connecting ramps are built, as shown in several of the studies between the BRA's southend by-pass the ramps to and from the south may be discontinued. However, until the Southend by-pass and its connecting ramps are built this ramp complex together with the Tremont Street - Columbus Avenue one-way pair will efficiently handle this traffic.

All service road arterial street and ramp volumes in this report are 1985 projections based upon the data indicated above.

It was further required that alternate profiles be developed on Route 695 west of Brookline Avenue to allow either a bridge or a tunnel crossing of the Charles River. In this regard all of the studies present herein permit this option.

In the development of this section of these routes it has been considered essential to develop not only the academic engineering matters of geometrics and traffic but equally important to relate the project in form to the neighborhoods and environments surrounding it.

This, for two basic reasons:

1. That those persons using these sections should enjoy as much as possible their traversing the routes and

2. That those living or working in or near the routes should not have imposed upon their neighborhoods a work with which they can not on the long time basis live happily.

In regard to the first of these, consideration was given to the impact which the new Boston skyline would have on the people entering the City from the Southwest Expressway. It was considered desirable that those traveling by car from the Southeast and the John F. Fitzgerald Expressways to enjoy the view of Boston cultural center and the Cambridge skyline if possible to do so. Those traveling in the reverse direction did not appear to warrant equal consideration if a choice needed to be made.

In regard to its effect on the neighborhoods through which it travels three principles were followed in addition to the engineering principles outlined above.

Because of the highly durable character of the Inner Belt and its tremendous size in relation to any geographic or urban area in which it is located, its design must be controlled by three basic principles in addition to carrying out its functional mission:

1. That it will not destroy, unwittingly, any existing architectural, historic, or other desirable values.
2. That it will complement any existing or proposed future values.
3. That in areas which are nondescript or in need of rehabilitation, it will be the seed to induce good adjoining development.

With these thoughts in mind our architectural treatments therefore were developed as to original form and placement of the individual engineering elements rather than as a rustication or wall-papering technique of a predetermined engineering form.

A portion of the Inner Belt passes through the Fens and was given special consideration and treatment because of the cultural and recreational activities immediate to it. The Fens, a public park developed by Frederick Law Olmstead over eighty years ago, is a long standing Boston landmark. In preparing the basic design for this section we have attempted to maintain the continuity of the Fens green belt by combining a depressed highway with a partial overhead landscaped cover. The various schemes shown in this report are attempts at carrying out this scheme with the exception of the totally open cut which leaves little of this section of the Fens intact.

Close contact has been maintained with the desires of the Boston Redevelopment Agency which acts as the City's planning board. In the Roxbury area their desire to increase the institutional land uses provide new and enlightening residential areas where rundown conditions now exist have been taken into acoount as has been the projected street circulation patterns which they feel essential to these developments. To varying degrees the various plans represented in this report carry out the ideas expressed to us by the B.R.A.

Possibly

Firm discussions as to the needs of the Massachusetts Bay Transportation Agency have been less easy to come by. It is believed, however, that by leaving the New Haven Railroad right-of-way intact and by the proper location of ramp complexes that sufficient latitude has been provided for expansion of their facilities and terminals for indicated bus-subway interchange points.

SOILS AND FOUNDATION PROBLEMS

The Inner Belt Expressway location is in the middle of two very poor soils areas - the Muddy River and Fen's Pond River beds and the Fort Point Channel south bay.

The Southwest Expressway lies largely on good ground where the ledge is close to the surface and over burden is quite stable.

In the early studies the accumulated soils data available from the Boston Society of Engineers was used to determine the probable nature of structures that could be built along the location corridors. An extensive exploratory boring and soils testing

program was then accomplished based upon the indicated structures to carry the various roadways.

At the conclusion of the boring program the various structural devices were reviewed and corrected or confirmed.

Appendix A carries the entire findings of the soils borings and testing program and the effect the findings can have on the highway structures. Various alternate treatments can be used as shown in this report.

MUDDY RIVER PROBLEMS

Since a below grade expressway through the Fens would intercept the Muddy River a special study was performed to see: a) If such a below grade expressway was feasible and; b) to determine various feasible solutions to the carrying of this water.

Aside from the academic hydrology problem was the fact that if the Muddy River run-off was merely diverted to the Charles River by a conduit the stream and ponds which constitute much of the naturalness of the Fens would be dried up. Accordingly, a scheme was developed to permit a portion of the water to remain in the Fens and the rest to be taken off by way of the existing Brookline Avenue conduit. Some occasional flooding in the Jamaica way area will be corrected by the recommended design.

Appendix B is the study of this problem, it includes the hydrologic computations and the detailing of a recommended design for this area.

UTILITY AND PUBLIC FACILITIES

The Fens

The principal public facility effected by the construction of this project in the selected corridors is the effect it has on the public park and recreation facilities in that part of the Fens from Evans Way to the Highland Branch of the M.B.T.A.

Independent appraisal of the commercial land values of this piece of property was placed at $5.00 a square foot and best probable use as that for high rise and high cost residential apartment developings. Since the replacement of such public land and facilities is chargeable to the total cost of the expressway this appraisal was made.

In addition, the reproduction cost of existing park, parkway and recreational facilities was analized and estimated.

An appraisal of the cost to reproduce in kind the public facilities in the Fens was made. The total cost of these is estimated to be $2,600,000, the value of the land is estimated at $4,999,000 with a total of $7,599,000.

Accordingly, various schemes were investigated to retain these or equivalent values in place on the basis that if replaced on the same site these costs would be avoided. In the case of the fully covered and landscaped tunnel and the partially covered and landscaped schemes it is believed that the above costs can be wholly avoided. The plans attached give the detail handling of this matter.

Because of the value of abutting land values and the uses to which they are part, no consideration was given to an elevated highway through the Fens.

Other important utilities which would be effected are as follows:

Southeast Expressway Interchange

If the additional service road through the Southeast Expressway is approved the circular track of the N.Y. N.H. and H. R.R. will need a short segment relocated.

Proposed 10' X 18' Fort Point Channel South Bay Conduit under construction will be uneffected although in at least one scheme it may need to be bridged by one ramp.

Massachusetts Avenue - Hampden Street Utilities

Large gas, sewer, water, telephone and power facilities will be bridged under schemes to go over Massachusetts Avenue or be relocated if the roadway is depressed as shown in other schemes.

Hampden-Albany-Fellows Street Utilities

Large gas, sewer, water, power and telephone lines are effected. To be handled as in the case of Hampden-Massachusetts Avenue.

Harrison Avenue

Large sewer and below ground power lines will need to be relocated or bridged.

Washington Street

The M.B.T.A. has an elevated railway over this street. Investigation was made for supporting it if the Inner Belt Expressway went under and going fully over it if the Inner Belt Expressway is elevated.

The cost of either scheme does not involve sufficient incremental cost to warrant the removal of the elevated railway under this expressway project.

Tremont-Columbus Avenue Utilities

In these streets and those aligned nearby, two large water - 30" and 48", large sewer, power and telephone will need to be relocated or bridged.

The M.B.T.A. trolley lines on Tremont can be left in place. In one scheme they will be carried on a bridge over a ramp and the Inner Belt Expressway elements, in others these tracks will be bridged.

The Stony Brook Conduits

This was the subject of a separate investigation and is treated in detail in Appendix C. Briefly the top will need to be reinforced in some areas; siphons will be needed under several of the schemes and small relocations will be necessary to carry out various of the expressway schemes included in this report.

N.Y., N.H., & H. R.R. Main Line

Except for bridging over or under these lines, no interference in the present location and grade is anticipated.

Huntington Avenue

Under all expressway schemes developed the large water (42") sewer (66"), telephone, power and storm drains will have to be relocated and siphons provided.

The M.B.T.A. trolley tracks can be incorporated in the bridge carrying this street, or cut back and discontinued if this proposed M.B.T.A. plan is carried out prior to construction.

The Fenway

The 9 foot M.D.C. sewer need not be touched in the Fenway under the various schemes studies, some power, and the 66" Boston sewer will be.

Brookline - Boylston Street

Large water, sewer, including the M.D.C.'s 9' Muddy River Conduit will be disturbed as will many power, telephone lines.

The 9' 8" conduit now taking part of the Muddy River flow under Brookline Avenue will need to be reconstructed in part to continue this service.

M.B.T.A. Highland Branch

Under all schemes studies this line will be carried in its present location and grade over the expressway. Under a restudy of the 1962 report scheme it will be bridged over.

N.Y. Central R.R. - Boston & Albany Division

Under the schemes studied this line will be carried in its present location and grades over the expressway. Under a restudy of the 1962 Report scheme it will be bridged over.

Beacon Street

This street carries heavy sewer, power and telephone lines. These will be disturbed except the 9' M.D. C. sewer.

The tracks of the M.B.T.A. will not need to be disturbed except that under one scheme, to provide at-grade crossings of motor vehicles from one of the ramp schemes it will need to be paved between the tracks to permit this crossing. Additional electrical safety controls of the trolley lines as they leave and approach the subway section will be needed.

Along the Southwest Expressway the following major utilities will be effected:

Roxbury Crossing

To relocate and provide adequate clearances for Tremont Street at Roxbury Crossing a new bridge carrying the N.Y., N.H. & H. R.R. is anticipated. Two different schemes are shown for this. Major water, sewer, telephone and power line changes will be encountered.

Jackson Square

The Stony Brook storm water conduit is effected here. Appendix D covers this matter. Other sewer, water, telephone and power lines will be effected.

Along existing Columbus Avenue major sewer, water, telephone and power lines will be effected and are recommended for relocation for the most part.

ACCURACY OF DATA

The studies were based upon 200' to the inch and 100' to the inch photogrammetric maps provided by the Massachusetts Department of Public Works.

Vertical errors ranging to 5' were disclosed in these maps. Wherever available City of Boston street and curb grades were used to correct the more obvious errors. Otherwise the geometrics are limited to the accuracy of the maps as corrected.

The location and ground level at all borings were separately determined by ground survey with ties to existing monuments in the area.

Because of the age of the maps, field check was made of all existing buildings in the study corridors to eliminate all buildings which have been torn down.

Utility data was separately obtained from the records and plans of owning agencies.

STUDY SECTIONS

For the convenience of making this study in relatively homogeneous units, and for the break down of the various construction and right-of-way cost estimates, the plans, estimates and descriptions of schemes studies are broken down into the following five sections:

Section 1
Southeast Expressway Interchange to Southwest Expressway Interchange
Massachusetts Avenue to Cabot Street
Station 10+00 to 59+70 Northbound

Section 2
Interchange of Inner Belt and Southwest Expressway
Cabot Street to Tavern Road and Ruggles Street to Prentiss Street
Station 59+70 Northbound to 80+00
Station 54+60 to 75+00

Section 3
Southwest Expressway Interchange to end of Fens
Tavern Road to Brookline Avenue
Station 80 to 114+ 20 Northbound

Section 4
Fens to Town of Brookline
Brookline Street to Beacon Street
Station 114+20 to 140+00

Section 5 Jackson Square to Inner Belt Interchange

Center Street to Prentiss Street

Station 14 to 54+60

Because of the need for alternate details studied within these sections, subsections were determined for such purpose. These subsections and the alternates are described in the study text that follows for each scheme.

Scheme A

See Plans 1A, 2A, 3A, 4A

See Profiles P1, P2, P3, P8, P9, P10, P11,
P21, P22, P25, P26 and P27

The principal and major elements of this scheme are the inclusion of the vertical separation of the two roadways in Sections 1 and 2 through Roxbury wherein the northbound roadway is elevated all the way until it crosses the New Haven Railroad tracks and the southbound roadway is depressed as shown on Typical Section TS-1.

From the New Haven Railroad north, both roadways are depressed from Parker Street to beyond Beacon Street at the end of the study section. This requires similarly vertically displaced connections to the Southwest Expressway.

Through the Fens from Huntington Avenue to Brookline Street a cantilevered platform with side vent openings is included to carry the recommended relandscaping of the Fens.

More detail descriptions are as follows by Sections:

Scheme A - Section 1 - Southeast Interchange to Southwest Interchange (Massachusetts Avenue to Cabot Street).

Connecting with the existing pavement at the Fitzgerald Expressway just east of Massachusetts Avenue the northbound roadway is tapered out from its 3 lane section to the proposed 4 lane

section over Massachusetts Avenue and all other streets by means of a cantilevered, double pedestal bend design crossing over the M.B.T.A. elevated at Washington Street inbetween Madison and Sterling Street.

The southbound 4 lanes are carried depressed through this area alongside the footings of the above bents.

A service road east of the improvement and through the Southeast Expressway Interchange has been provided. This service road is not essential to the construction, without it this street level flow would be on Albany Street or on a new street alongside the road proposed by the B.R.A. Since it is estimated that it will carry 860 vehicles per peak hour its desireability lies in that it not only extends the service road carried on the east and south sides of the entire project (partly along Ruggles Street) but it removes from turning movements and weaving operations this flow from the critically loaded Southhampton - Massachusetts Avenue section east of Albany Street.

This service road will require some rebuilding of the present Southeast Expressway interchange to provide adequate headroom clearance and to re-orient two bents of the previously constructed works. It will cost $1,610,000. Considering the traffic assignment to it and its aid in clearing up tight operations in the ground pattern it is believed that this service road is warranted.

The on-ramp from the Southhampton Street-Massachusetts Avenue ground pattern to the Fitzgerald Expressway has been located for righthand entering on the light volume section of this interchange.

This ramp position will cause the abandonment of the left hand entering ramp previously constructed for this purpose. On the whole expressway system this left hand entering ramp is the only one. Its peculiarity can only cause driver confusion at this high volume area. It will also cause other expensive construction to reduce its Massachusetts Avenue terminal conflicts.

Ramp from SWX to IB Northbound

Ramp from IB North to SWX West

While the ramp traffic assignment is not heavy (100 vehicles per design hour) its switch to the right hand side is considered to be warranted.

An on-ramp to the northbound elevated section is provided by a ramp on the east side of Albany Street. Albany Street will have to be widened on the east side and operated one way in a southerly direction.

An off-ramp from the southbound depressed expressway to a service road paralleling the south and east of the expressway is provided for traffic bound for this vital industrial and commercial area.

A service road is also provided paralleling the west and north side of the expressway. These service roads, indicated

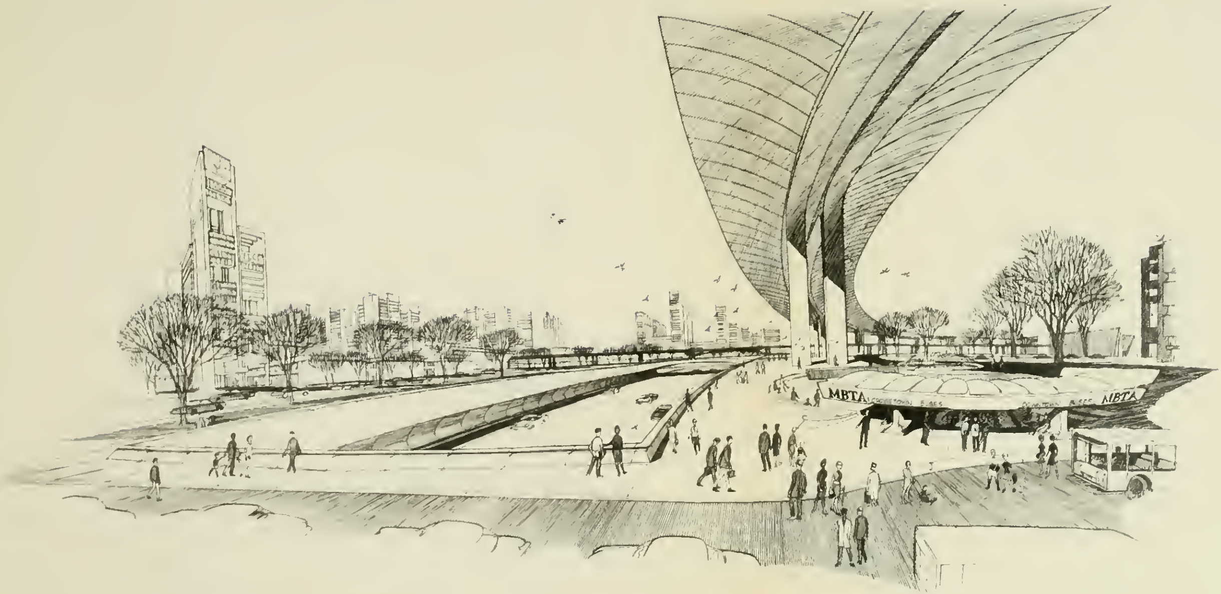
for one directional flow at street level, are proposed at 34' to 38', in width and will distribute ramp and local traffic to the various arterial streets in this area.

Mainline		
	Pavement width	Northbound - 62' including shoulders Southbound - 62' " "
	Maximum curve	Northbound - 1400' radius Southbound - 1400' radius
	Maximum grade	Northbound - +4.0% - 1.8% Southbound - +4.0% - 0.5%
Ramps		
	Width	26'
	Maximum curve	125' radius
	Maximum grade	+4.5% - 5.0%
Service Roads		
	Width	East Side - 34' - 38' West Side - 34' - 38'
Streets closed		Reading Street Webber Street Chadwick Street Fellows Street

Architectural rendering, Exhibit 2 is looking North on this section.

Modifications within Scheme A, Section 1.

Plan sheets 1B and 1C show variations in the ground and ramp pattern.



ROXBURY SECTION
VIEW FROM HARRISON AVENUE LOOKING NORTHWEST

THE CLARKESON ENGINEERING COMPANY
CAMPBELL, ALDRICH AND NULTY ARCHITECTS

Scheme A - Section 2

Interchange of Inner Belt and Southwest Expressway.

The position of the two roadways of the Inner Belt remain the same through this area with the northbound lanes elevated and the southbound depressed to Parker Street from which point they are both depressed under Parker and Huntington Avenue.

In order to permit the ramps connecting the northbound lanes with the Southwest Expressway to be carried over the southbound lanes with single spans of the concrete box girder type used on the remainder of the elevated structure, it was necessary to separate the north and southbound lanes far enough to reduce the crossing skew. The maximum distance between roadway centerlines is approximately 220 feet.

Between the leaving and entering ramps servicing the Southwest Expressway the lanes along the Inner Belt have been cut to three. Substantially reduced traffic requirements at this section permit this reduction.

The connectors to and from the Southwest Expressway, four in number, are each two lanes with disabled vehicle shoulder of 10 feet on the right and clearance shoulder of 4' on the left. These connectors are laid out for 40 mph operating speed to avoid taking any of the buildings in the Roxbury housing project off Ruggles Street.

Service roads are provided on each side of the Inner Belt through the interchange. Ruggles Street performs this service for part of the service road on the west. A new service road is

proposed for the remainder of the way. Requires a loop to be made on Tremont St.

The east service road follows existing Windsor Street to Shawmut Avenue and thence on new alignment to Parker Street.

Tremont Street provides the southside service road in the interchange area. No change in location is required. It is recommended that it be operated one way downtown.

Columbus Avenue provides the northwest side service road through the interchange. It will require relocation against the New Haven Railroad embankment. It is recommended that it operate one way south.

A northbound on-ramp from the east service road to the northbound roadway of the Inner Belt Expressway is provided.

A southbound off-ramp from the southbound expressway to the eastside service road and Tremont Street is provided.

We won half of interchange so far

In positioning the roadways and ramps in this interchange a set of direct connecting ramps from the proposed B.R.A. southend by-pass to the Southwest Expressway are proposed. They are shown in plan 2D. When the southend by-pass is built their ramps will be very useful and will permit the reduction in traffic usage proposed by the B.R.A. Until that time the one-way pairing of Tremont and Columbus, proposed herein will amply handle their flows.

While these direct connecting ramps are recommended their construction should be delayed until the Southend By-pass

is constructed.

This will suspend the expenditure of $2,102,000 the value of these ramps.

Mainline

Pavement width	Northbound	50' - 62' including	
	Southbound	50' - 62' shoulders	
Maximum curve	Northbound	4600' radius	
	Southbound	4600' radius	
Maximum grade	Northbound	-4.5%	6.25%?
	Southbound	+0.5%	

Connectors

To and from Southwest Expressway

Width	38'	
Maximum curve	600' radius	
Maximum grade	+4.8%, -5.0%	6.25%?

Ramps

To and from ground pattern

Width	22'
Maximum grade	+5.5%, -4.5%

Service Roads

Width	East Side	34'	Not between Shawmut - dar
	West Side	34'	5
	Ruggles Street	50'.	
	Tremont Street	58'	- 84'
	Columbus Ave.	38'	- 40

Streets closed

Cabot Street on west

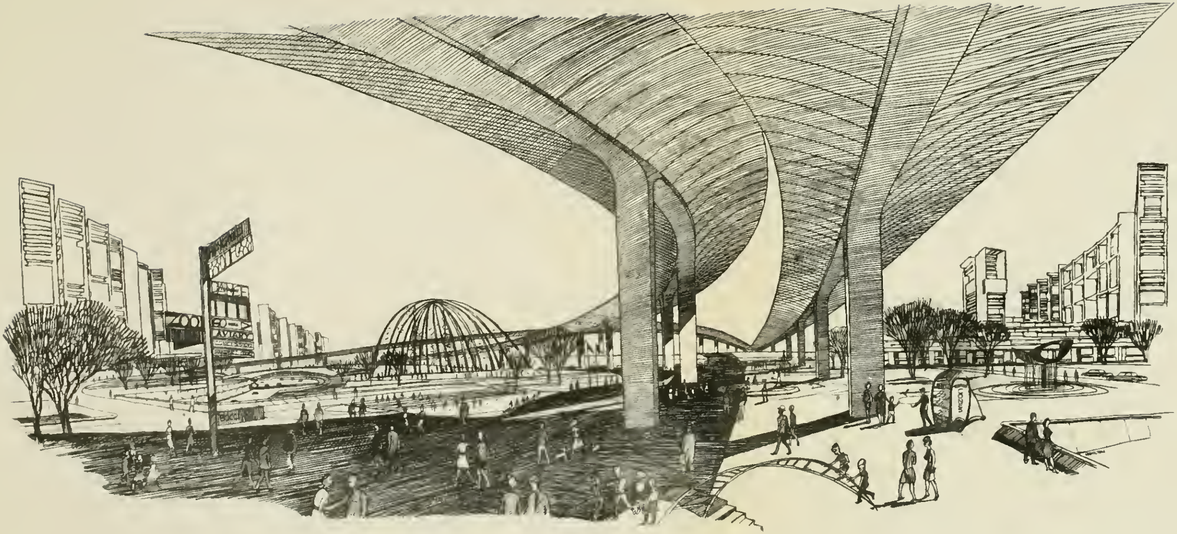
Weston Street

Leon Street

Tavern Road

Architectural rendering, Exhibit 4, shows a view of this interchange area.

On one of these altermates the existing left hand entering ramp is maintained. Both,otherwise maintain more nearly existing street patterns. Since this is a congested area from the stand point of street traffic flows and turning movements the plan shown on plan sheet 1A is preferred.



THE INTERCHANGE
VIEW UNDER THE INTERCHANGE

THE CLARKESON ENGINEERING COMPANY
CAMPBELL, ALDRICH AND NULTY ARCHITECTS

Scheme A - Section 3

Tavern Road to Brookline Avenue

Through this area both roadways are depressed and adjacent. They are covered in part by a cantilevered "T" section to permit the replacement of a landscaped area over the roadways. A 20 foot opening running longitudinally along each side and over the right-hand lane and shoulder has been provided to reduce ventilating costs, provide daylight and permit fire fighting so that dangerous cargo verhicles will not be excluded from using this section. Emergency fire doors and exits are provided for in the cost estimate.

The roadways are adjacent in the block between the Fenway and Hungtington Avenue. This will permit extension of the Fens landscaping to Hungtinton Avenue to replace that lost in Section 4 between Brookline Avenue and the Highland Branch of the M.B.T.A. and it reduces the forced alignment of the Inner Belt Expressway which would be necessary at this critical point to avoid taking the properties in this block.

While this recommendation increases the cost of right-of-way it permits better alignment and it reduces construction costs which would be encountered in protecting these structures during construction.

Alternate plans for the saving of these buildings are shown on plan sheets 3C and 3D which demonstrates their conditions.

One way South, I believe

A service road is provided on the west side only along existing Fenway. This road is needed to service institutions on this existing street. With the ramp provided southeast of Parker Street and the limited use of the expressway in this area, a full service road on the east side in not believed warranted.

The section of Park Drive adjacent at this section is recommended for expansion to 4 lane operating width to match with the rest of Park Drive.

One off ramp from the northbound roadway starts in this section for traffic wishing to go to the Park Drive and Beacon Street area.

Lighting will be necessary in this partial tunnel, which is 3600 feet long. Some ventilation, too, will be needed. They are both provided for in the construction cost estimate.

Mainline			
	Pavement width	Northbound	62' including shoulder
		Southbound	62' " "
	Maximum curve	4600' radius	
	Maximum grade	Northbound	+0.4%, -4.5%
		Southbound	+0.5%, -0.4%
Ramps			
	Pavement width	26'	
	Maximum grade	+5.5%, -4.5%	
Service Road			
	Width	Fenway - existing width, 34' where realigned Park Drive - 50'	

Streets closed

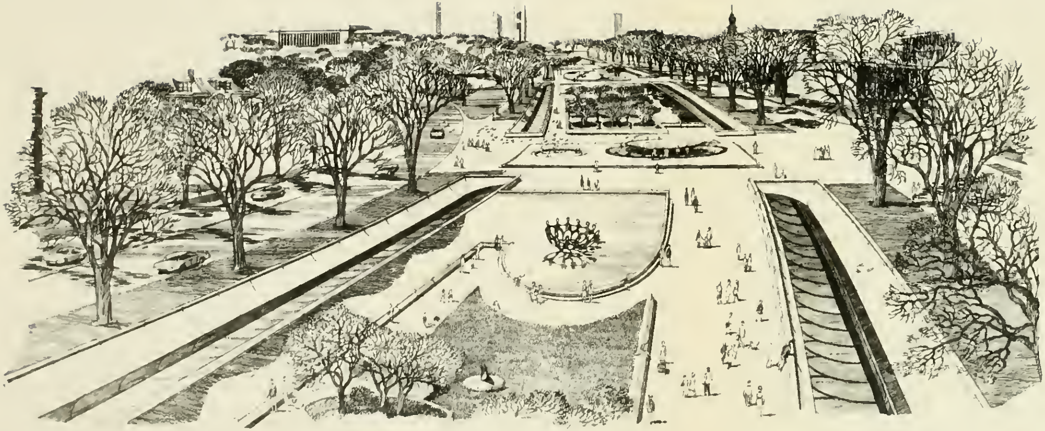
Avenue Louis Pasteur

Architectural sketches in Exhibits 5 and 6 depict this section.

Alternate conditions studied in this area include:

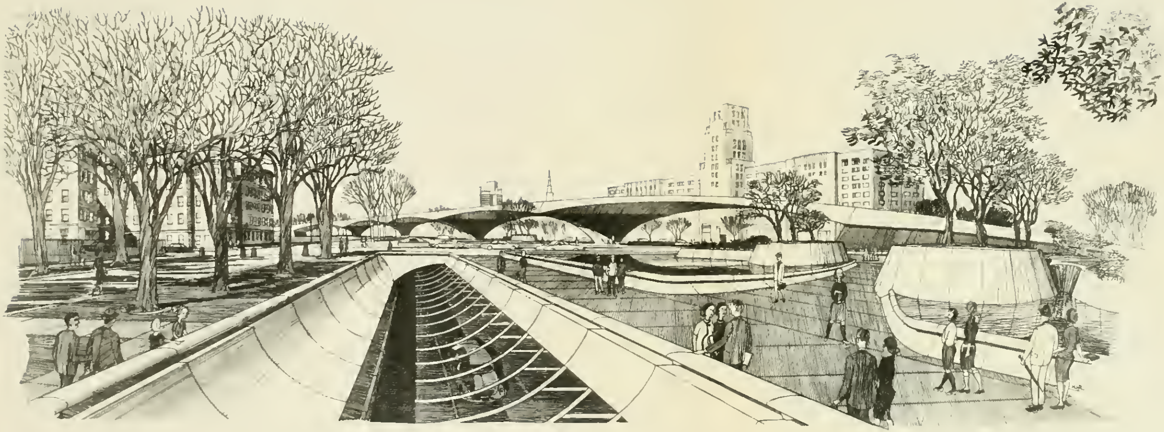
a. Separate tunnels between the Fenway and Huntington Avenue to reduce the cost of right-of-way. This alternate is shown on plan sheet 3C. This alternate forces the alignment of the main raodways at a point near the connectors to and from the Southwest Expressway. This sharpened curvature will obscure the ramp openings for these very heavy two lane flows not unlike the hidden ramp from Route 128 to U.S. Route 1 in Dedham and will, it is believed cause considerable traffic operating difficulty. In the 1962 Report where this split was recommended the ramps to and from the Southwest Espressway were far enough away not to cause this trouble. Due to the change in location of the interchange, however, this alternate is considered inadvisable. The saving in right-of-way cost would be $1,615,000 which would be partially offset by an increase in construction cost to support the buildings during construction and to provide service to them.

b. A full tunnel section through the Fens without the longitudinal openings is shown on Typical Section TS-5. This alternate would increase the lighting costs and materially increase the ventilating costs. Further it would require either large ventilation shafts over the tunnel in the Fens



THE FENS
VIEW FROM BROOKLINE AVENUE LOOKING SOUTH

THE CLARKESON ENGINEERING COMPANY
CAMPBELL, ALDRICH AND NULTY ARCHITECTS



BRIDGE AT RIVERWAY
VIEW FROM FENS LOOKING NORTH

THE CLARKESON ENGINEERING COMPANY
CAMPBELL, ALDRICH AND NULTY ARCHITECTS

area or numerous smaller shafts at as close spacing as 100 feet to reduce the ventilation ducts and costs.

More importantly, vehicles carrying dangerous cargoes would be excluded from this section and would therefore have to leave the Southwest Expressway near Jackson Square or at Massachusetts Avenue. Since all vehicles cause their proportion of traffic congestion and hazard on the streets and all vehicles are taxed for this Interstate program, it does not appear warranted to proceed with a design in this manner.

c. A third alternate is to leave the expressway in open cut through the Fens.

This would save $8,510,000 but it would wholly destroy the Fens for this entire stretch and adversely affect the institutions abutting this public park.

The saving, inviting though it might be, is not considered warranted particularly since the land value of the Fens ($4,999,000) and the replacement cost of the existing landscaping and recreational facilities would have to be replaced at a cost of $2,600,000 thus reducing the savings to $911,000.

d. The possibility of an off ramp from the southbound roadway to Huntington Avenue was considered. This alternate ramp would conflict with the acceleration lane for the on

ramp coming from the Beacon Street interchange and would be close to the off connector to the Southwest Expressway. Driver confusion and forshortened weaving distances would result.

Since an adequate ramp can be put in to Tremont Street as shown on plan sheet 2A, this ramp would not be warranted. Both are not needed and the operating characteristics of the ramp to Tremont Street are materially better.

e. A service road connection from Huntington Avenue to Park Drive on the east side of the Expressway is shown in Plan Sheet 3D.

This service road is not needed since the same service is provided by the ramps either side of this area and by the under capacitied expressway here. Such a service road would further cut up the Fens, cost $198,000 for construction and cost $513,000 additional for land and replacement of recreational facilities. It is not recommended.

Scheme A - Section 4

Brookline Avenue to Carlton Street

In this scheme all lanes of the Inner Belt through this section are adjacent and below ground and pass under Brookline Avenue, under the Boston and Albany division, under the Highland Branch of the M.B.T.A. and under Beacon Street.

No landscaped platform is provided because of the need for the roof space for ramps necessary to serve the Beacon Street to and from the Street pattern interchange.

Because of the configuration of the interchange it was necessary to go beyond the Brookline Town Line to accomplish this set of ramps.

The profile of the main line roadways is held at a position to permit connection within standards to a connection with the Charles River Crossing whether it is by bridge or tunnel.

As stated previously, it is considered best that this interchange be located in the Beacon Street area to keep the ramps as far from the Southwest Expressway Interchange as possible for smoother traffic operating conditions. The tight ramp pattern, which keeps the expressway ramp left-turning and cross movements separated from Beacon Street is elongated and of minimum curvature to reduce land takings in Brookline. Particularly it was desired to miss the large apartment building on Medfield and St. Mary's Streets.

Park Drive was left intact on the eastside to serve as a service road between Brookline Avenue and Beacon Street, a similar service road is proposed on the west side between Beacon and Brookline and lines up with the Fenway. These service roads distribute not only local traffic but on and off ramp traffic to Beacon Street, the riverway westbound, Brookline Avenue, Boylston Street and the Fenway.

All movements including the weaving sections have been checked and are considered adequate for the traffic volumes projected.

Because of the large volume of passenger traffic along the Riverway to and from Park Drive a spearate bridge is provided to directly connect these two arteries and keep this traffic out of the Fenway-Brookline-Boylston Street intersection. It is projected that this bridge will remove 16,000 vehicles per day from this intersection or 870 per hour. The attraction of the new bridge at Park Drive and Commonwealth Avenue now being built by the M.D.C. may cause these volumes to be exceeded.

Consideration was given to placing this bridge into Boylston Street instead of Park Drive. Such an alignment would not serve the two directional flow provided by the M.D.C.'s new bridge over Commonwealth Avenue since its approach configuration does not permit easy access from this section of Boylston Street to the M.D.C.'s new bridge.

Without this bridge the additional 870 vehicles per hour through the Brookline Avenue-Fenway Park Drive intersection would not work at all. Jug handle channelization would be of little

help and the flow from Park Drive westerly to the Riverway if left on the street level would increase the congestion at the weaving sections on the west side service road as well as adding to congestion on Park Drive in front of the Sears, Roebuck Retail Store.

The effect of this additional congestion in these three areas would cause back ups on the ramps which could effect the operation of the Inner Belt itself.

Exhibit 6 shows a perspective of the proposed bridge connecting the Riverway with Park Drive.

Figures 1, 2 and 3 are the traffic patterns of the various effects which involve this bridge. Figure one shows the 1985 turning movements, ramp flows and weaving volumes with the bridge. Figure two shows the turning movements, ramp flows, weaving volumes if the bridge is not built but if the traffic still desires to use the Riverway-Park Drive complex to Commonwealth Avenue, Boylston Street and Storrow Drive.

Figure three shows this latter condition but on the assumption that much of the Riverway flow tried to use Brookline Avenue far in excess of its capacity. Considering the institutional and pedestrian use of this section of Brookline Street these added flows would be hazardous.

It is believed that in order to permit the Inner Belt ramps to operate efficiently to get on and off the Expressway, this bridge estimtated to cost $1,121,000 is warranted.

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CLARKESON ENGINEERING CO., INC.
ENGINEERS

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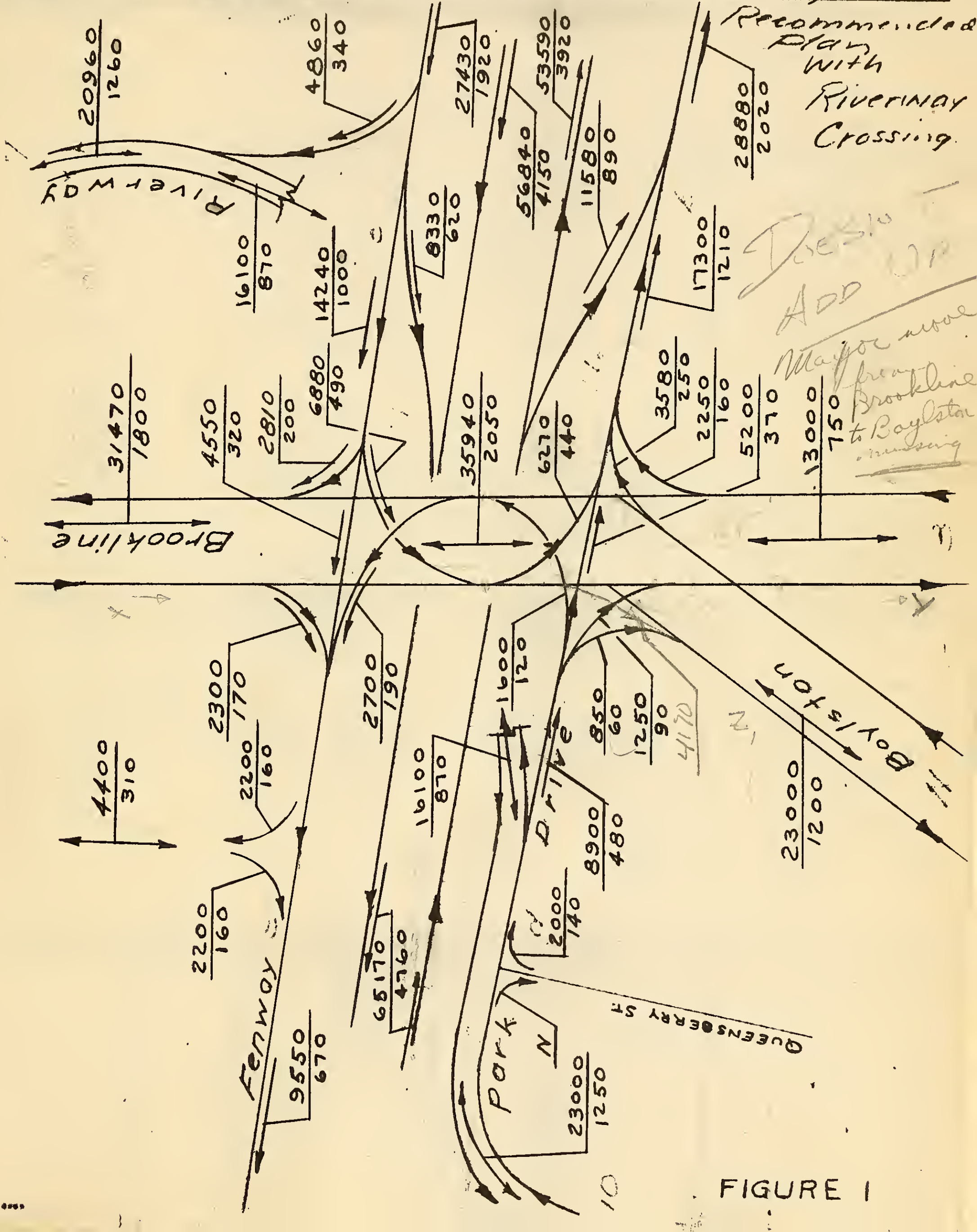
SUBJECT Vol. Detail Brookline Fenway Pk. Dr



Recommended Plan with Riverway Crossing

Doesn't ADD UP

Major move from Brookline to Boylston missing

FIGURE I

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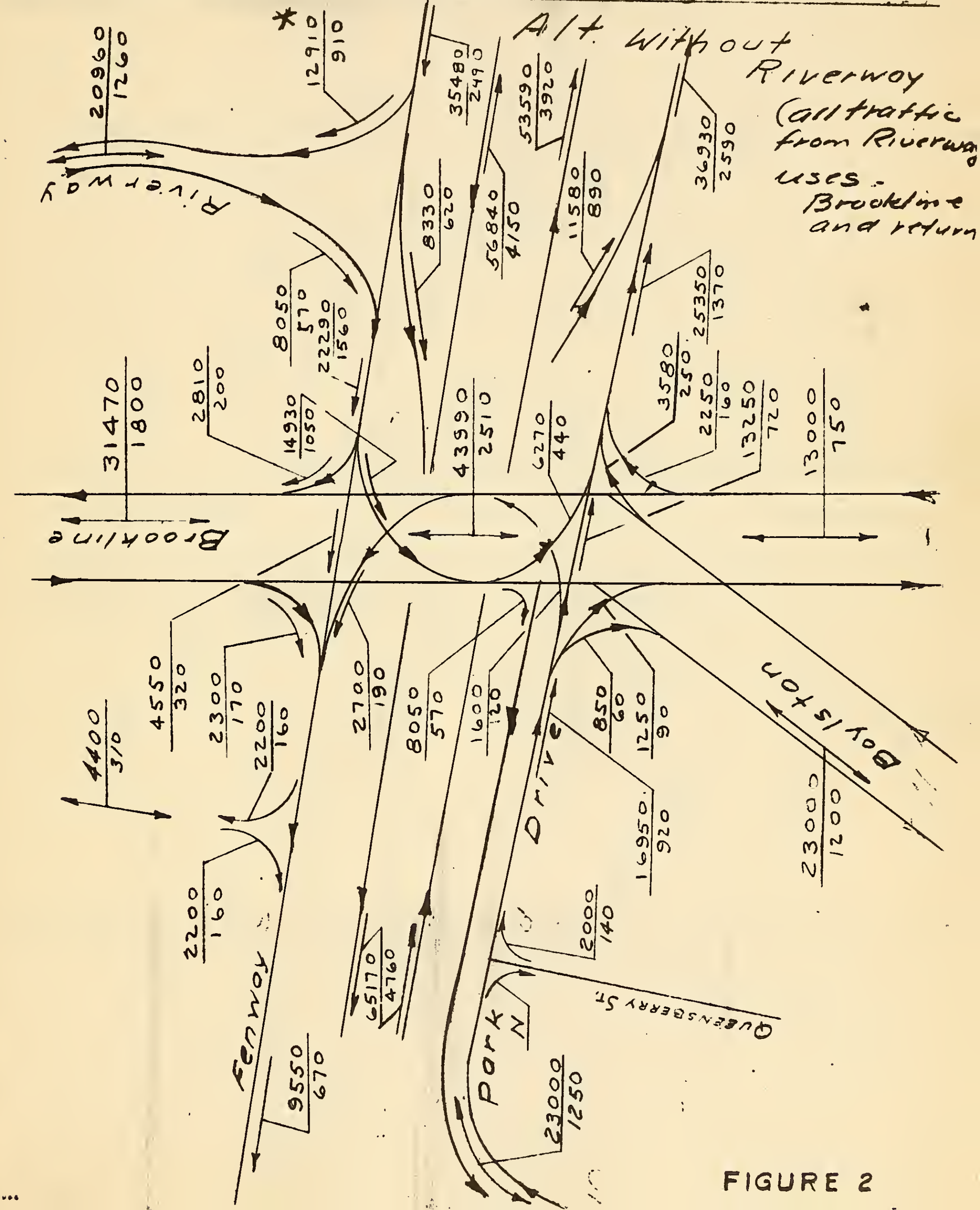

Alt without Riverway
(all traffic from Riverway uses - Brookline and return

FIGURE 2

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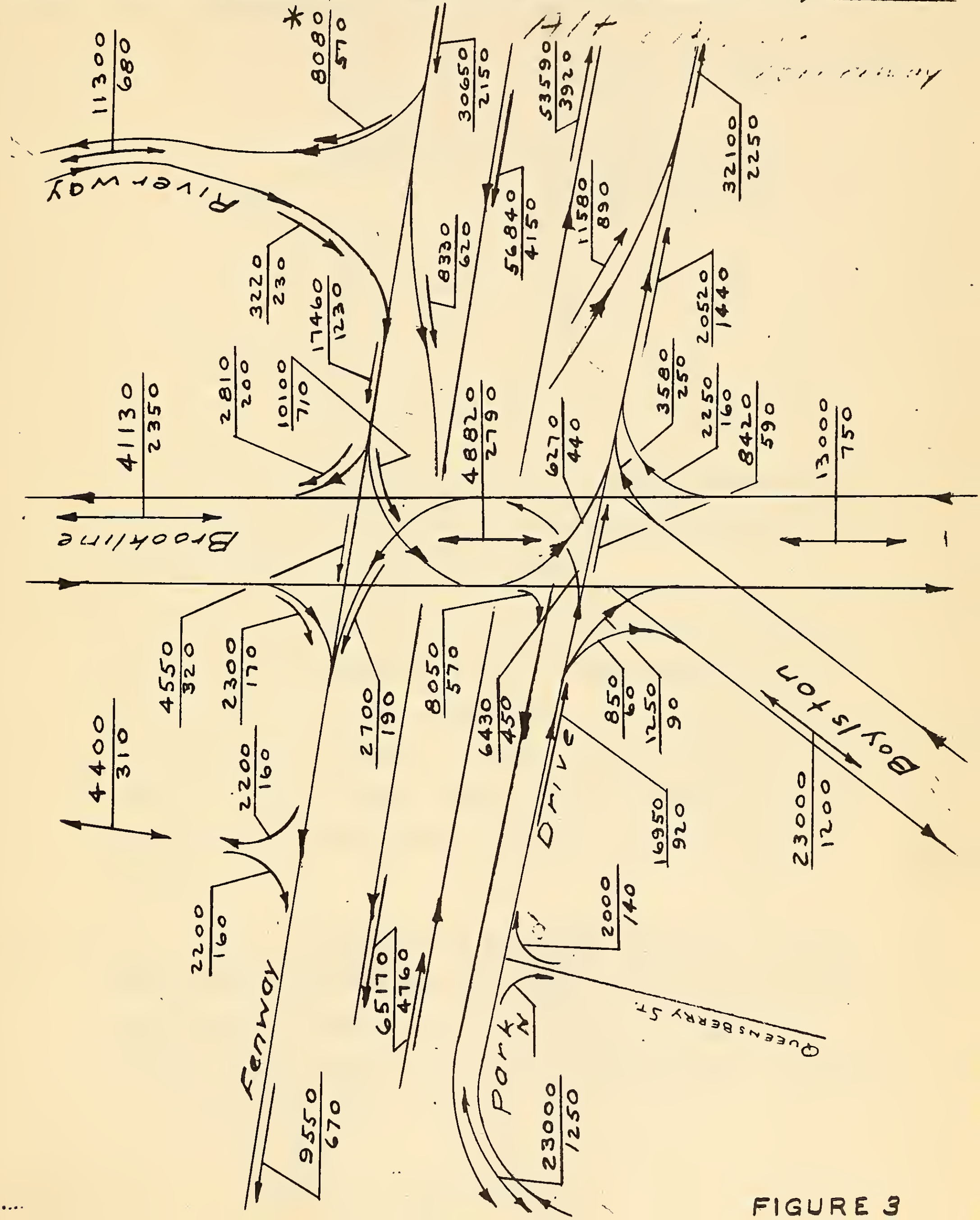

FIGURE 3

Main Line

	Pavement width	Northbound - 62' including shoulder Southbound - 62' " "
	Maximum curve	4600' radius
	Maximum grade	Northbound +3.4% -2.25 Southbound +2.25% -3.4%
Ramps		
	Width	26'
	Maximum curve	125' radius
	Maximum grade	6.0%

Streets closed

Buswell Street and Euston Street in Brookline

As modifications to this scheme an attempt was made to reduce the vertical depth of the expressway by having the ramp flows handled at grade on Beacon Street.

Figure four shows the ramp flow which would cross or make turns on Beacon Street. Inasmuch as Beacon Street is under present operating conditions, handling close to its capacity it is not believed warranted to attempt to place the left turns and crossing movements at grade on this street. Such an operating arrangement would back up traffic on the expressway ramps and produce congestion on the expressway.

Two schemes to do this were considered one shown on plan sheet 3B shows all movements at grade. The other shown on plan sheet 3 A shows the on-ramp cross flows only handled by separation structures. The all grade condition would save $468,000 but would produce

Rest of ¶ missing

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SHEET 1 OF 7
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SUBJECT Vol Detail Beacon Park Dr. S. Serv. Rd.

Recommended.

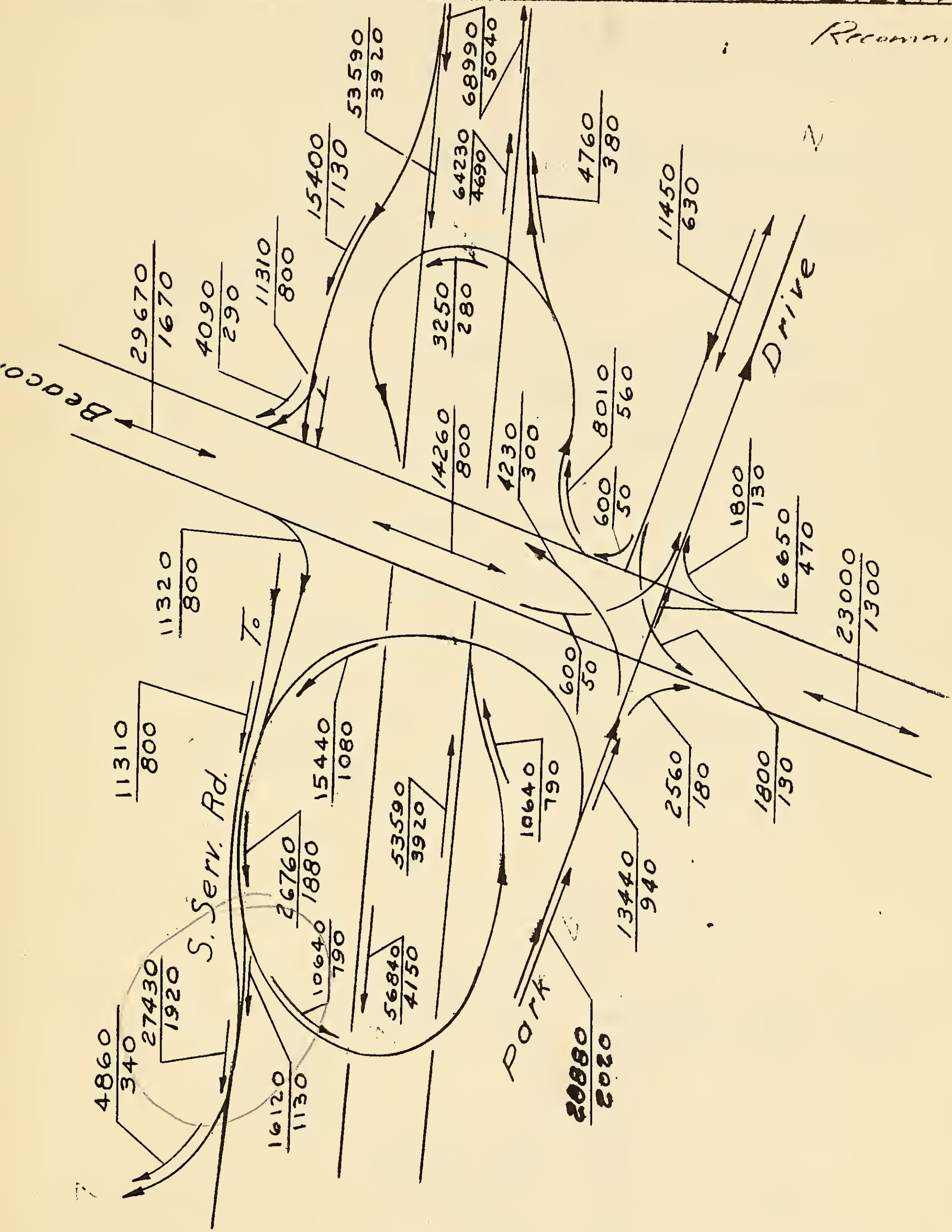


FIGURE 4

Scheme A - Section 5

Southwest Expressway From Centre Street to Prentiss Street

In this section all lanes in each direction are carried on embankment and adjacent to each other. Provision is made for a relocated Columbus Avenue adjacent to the New Haven railroad embankment to the west.

The terminal section at Jackson Square is drawn as though the extension of the Southwest Expressway would remain east of the railroad tracks. We have been informed that this may change. Until a decision is reached regarding the location of the next section, the plan shown here is purely tentative.

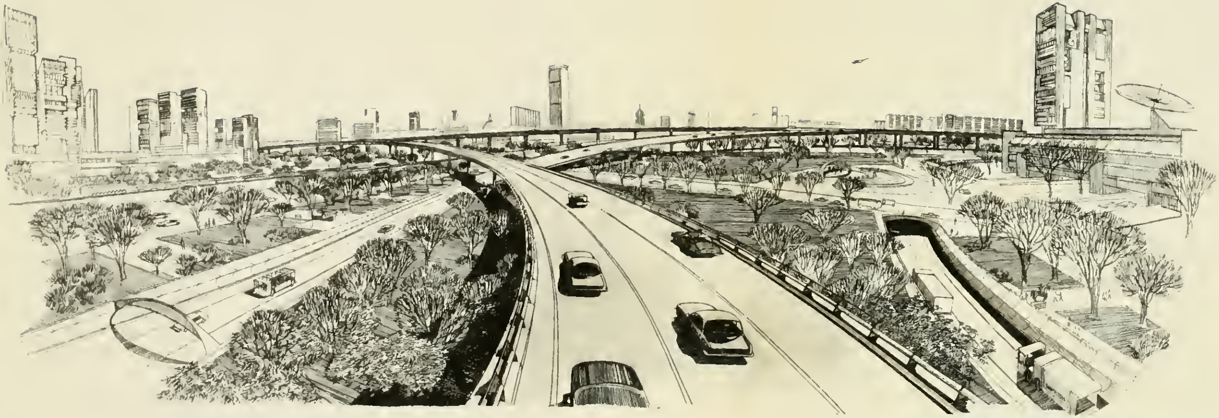
In this scheme Tremont Street relocated is considered one way into town and Columbus Avenue one way out. Ramp connections are made to these service roads to pick up and distribute the traffic. Space for these ramps is provided for in plan sheet 4A, which may be used for any of the schemes presented herein.

Main Line

Pavement Widths	Northbound 62'		
	Southbound 62'		
Maximum curve	3000' radius		
Maximum grade	Northbound	+0.5%	-3.5%
	Southbound	+3.5%	-0.5%

Ramps

Pavement width	26'	
Maximum grade	+4.9%	-4.0%



THE INTERCHANGE
DRIVERS VIEW APPRDACHING BOSTON

THE CLARKESON ENGINEERING COMPANY
CAMPBELL, ALDRICH AND NULTY ARCHITECTS

Service Roads

Tremont Street

Pavement width	38'	
Maximum curve	1000' radius	
Maximum grade	+4.9%	-4.8%

Columbus Avenue

Pavement width	38'	
Maximum curve	3000' radius	
Maximum grade	+5.0%	-4.0%

SCHEME B

Scheme B - Section I and II

See plan sheets 1B and 2B

See profile sheets P1, P2, P4, P12, and P13

The principal difference between this scheme and scheme A is the method of vertically separating the main line Inner Belt Expressway main roadways, between Massachusetts Avenue and Parker Street.

The northbound roadways are mounted directly above the southbound roadways in this area thus permitting a substantial reduction in the width of right of way required through this area including the Southwest Expressway interchange.

All other details of ramps, service roads, etc. of scheme A are retained and the section from Parker Street through the Fens to Carlton Street in Brookline are the same. The Southwest Expressway is the same as for scheme A.

However, all of the alternatives mentioned in scheme A are applicable to this scheme.

Typical Section TS-7 shows the principal characteristics of this scheme as it differs from scheme A as shown in Typical Section TS-1.

The perspective structural arrangement is shown in Exhibit 3.

Obviously, a considerable difference in property taking and buildings to be demolished is realized by scheme B.

Residentials displaced	
for scheme A	275
for scheme B	201
Commercials displaced	
for scheme A	78
for scheme B	67
Industrials displaced	
for scheme A	45
for scheme B	28

The principal disadvantage to this scheme is that all southbound Inner Belt traffic will be operating on a less open and daylighted roadway. Although it is expected that the northbound roadway will be up to 45 feet above the ground similar cases of this type of design in New Jersey indicate a dreariness in the lower roadway.

For the section of change from Massachusetts Avenue to Parker Street:

Main Line

Pavement width	Northbound	62'	including shoulder
	Southbound	62'	" "

Ramps

Pavement widths	26'	
Maximum curve	250' radius	
Maximum grade	-5.5%	+4.0%

Service Roads

Pavement width	34' and 38'	
Maximum curve	300' radius	
Maximum grade	+4.2%	-4.0%

SCHEME C

See plan sheets 1C, 2C and 3B

See profile sheets P2, P3, P6, P8, P11, P14,
P15, P16, P21, P22, and P23

Since the corridor of the Inner Belt was pinned down by prior approvals alternates such as this cover the same center line and general geometrics as scheme A. The principal difference is in the treatment in section 1 where all mainline expressway roadways are depressed through Roxbury in open cut section.

The Typical Section for this section is shown in TS-2.

As presented in plan the interchange with the Southwest Expressway remains partly elevated and partly depressed as in schemes A and B. An alternate was studied for this scheme and the costs are shown for depressing all major elements of this interchange (section2). Because of the complexity of ramps, and existing street patterns the interchange and mainline elements are lowered further into the ground and become more costly. Even with such lowering of the expressway and its ramps one connector was kept above to avoid greatly excessive costs and construction problems. Cost is still cheaper

Main Line

Pavement width	Northbound	62' including shoulder	
	Southbound	62' " "	
Maximum curve	1400' radius		
Maximum grade	Northbound	+4.0%	-4.5%
	Southbound	+4.0%	-2.25%

Ramps

Pavement width	27'	
Maximum grade	+6.0%	-6.0%

Connections to Southwest Expressway

Pavement width	38'	
Maximum curve	600' radius	
Maximum grade	+4.0%	-5.0%

Service Roads

Pavement width	34' and 38'	
Maximum curve	300' radius	
Maximum grade	+4.25%	-4.0%

All of the modifications which apply to schemes A and B in various localized areas apply equally to this scheme and can be considered as possible modifications thereof.

Because the side by side arrangements of the below ground mainline elements of the Inner Belt a greater width of right-of-way will be required. Scheme A saves approximately 40 feet of this width and scheme B approximately 70 geet of this width.

OTHER SCHEMES

Consideration was also given to the plan, profiles and cost of the scheme as developed and recommended in the 1962 Expressway Report with the change in location of the Southwest Espressway and interchange to the proximity of the New Haven R.R. embankment.

This scheme is still being worked on, its cost of construction and right-of-way being developed and will be the subject of a supplemental report.

Physical Effects on Property Takings

On Table 1. is summarized the numbers of buildings by various classifications taken by each of the schemes as presented here and by that modification which leaves the block between Huntington Avenue and the Fenway.

As shown in this table the least damaging to business, residences, etc., is by scheme B in which the northbound roadway is directly above the southbound roadway. This is obvious since it takes a considerably reduced width of right-of-way through the Southwest Interchange and through the Roxbury section to Massachusetts Avenue.

Although ground contours indicate on scheme B that the service roadways need to be widely spaced through the Southwest Interchange it is assumed that buildings between the interchange and the service road can continue to operate and not be considered within the taking.

While scheme A saves about 40 feet of width required through Roxbury the position of the roadways and its curvature and relation to service drives does not reduce the number of buildings taken from that of scheme C, the wider fully depressed section. The great amount of open land existing in Roxbury due to prior demolition also reduces these differences.

TABLE I

SUMMARY OF PHYSICAL EFFECTS

		NUMBER IN CATEGORY									
		USE OF STRUCTURES							OTHER DATA		
	SECTION NUMBER	Residential	Retail	Business	Institutions	Industry	Wholesale	Service	Vacant Lots	Partial Land Taking	Households Displaced
Scheme A	1	156	41	1	16	38	6	3	131	5	339
	2	73	18	1	16	5	4	5	50	2	186
	3	10	1	0	0	2	0	0	2	3	169
	4	36	0	6	2	0	0	5	4	0	151
	TOTAL	275	60	8	34	45	10	13	187	10	845
Scheme B	1	111	35	0	8	24	4	4	91	5	239
	2	44	17	0	9	4	4	5	26	1	109
	3	10	1	0	11	0	0	0	1	6	169
	4	36	0	6	1	0	0	5	4	0	151
	TOTAL	201	53	6	29	28	8	14	122	12	668
Scheme C	1	156	41	1	16	38	6	3	131	5	339
	2	73	18	1	16	5	4	5	50	2	186
	3	10	1	0	0	2	0	0	2	3	169
	4	36	0	6	1	0	0	5	4	0	151
	TOTAL	275	60	8	33	45	10	13	187	10	845
Museum School By-pass	1	156	41	1	16	38	6	3	131	5	339
	2	73	18	1	16	5	4	5	50	2	186
	3	10	1	0	0	5	4	5	2	4	169
	4	26	0	6	0	0	0	4	0	6	25
	TOTAL	265	60	8	32	48	14	17	183	17	719
S.W.Exp	5	121	40	1	6	15	3	14	38	0	314

COST SECTIONS

1. Massachusetts Avenue to Cabot Street.
2. Cabot Street to Tavern Road and Prentiss Street to Ruggles Street.
3. Tavern Road to Brookline Avenue.
4. Brookline Avenue to St. Mary's Street.
5. Centre Street to Prentiss Street.

Cost Estimates:

Table II which follows shows the estimated construction costs and estimated costs of rights-of-way for each scheme, broken down by the previously described construction sections.

These construction cost sections, five in all including the section of the Southwest Expressway, also are our recommendation for breaking this work into construction contracts. Although some are sizeable the largest for section One have a continuity of construction permitting the greatest construction economy due to repetitive type of work.

Full consideration was taken in arriving at unit designs and unit prices for the greatest use of pre-cast type of construction. Since this type gives not only better control of concrete and other items but permits year round construction and other economies.

The total cost of the facilities for the Inner Belt are surprisingly close though considerable difference does exist in the various construction types. The cheaper group is with all construction under ground, Scheme C; and when the landscaped platform is omitted from the Fens area and the Beacon Street Interchange involves all turning movements at grade. If the Fens is covered either by a cantilevered platform or full tunnel section, when the Fens is thus restored the total cost of this scheme is comparable to the others considered.

PROJECT COSTS

IN THOUSANDS OF DOLLARS

TABLE II

	COST SECTION			AS PRESENTED WITH THE FOLLOWING MODIFICATIONS											
			As Presented	I Beacon St. Interchange At Grade	II North Bound On Ramp Over Beacon St.	III Tunnel Thru Fens	IV Open At Fens	V Fens Frontage Roads	VI Museum School By-pass	VII Museum School By-pass w/ Fens Frontage Rds.	VIII Southend By-pass Connection	IX Inner Belt Over Mass. Ave.	X Mass. Ave. Ground Pattern Alternate 1	XI Mass. Ave. Ground Pattern Alternate 2	XII Central Artery East Service Drive
Scheme A	1	Construction	26,047	26,047	26,047	26,047	26,047	26,047	26,047	26,047	26,047	22.051	26,022	25,786	27,462
		Right of Way	3,364	3,364	3,364	3.364	3,364	3,364	3,364	3,364	3,364	3,364	3,439	3,320	3,559
	2	Construction	19,286	19,286	19,286	19,286	19.286	19,286	19,286	19,286	20,849	19286	19,286	19,286	19.286
		Right of Way	7,895	7,895	7,895	7,895	7,895	7,895	7,895	7,895	8,475	7,895	7,895	7,895	7,898
	3	Construction	23,744	23,744	23,744	24,704	17,155	23,937	25,960	26,153	23,744	23,744	23,744	23,744	23,744
		Right of Way	2,879	2,879	2,879	2,879	* 7,599	3,392	1,264	1,541	2,879	2,879	2,879	2,879	2,879
	4	Construction	20,131	19,663	20,383	20,775	18,205	20,131	20,131	20,131	20,131	20,131	20,131	20,131	20,131
		Right of Way	5,383	5,383	5,383	5,383	6,824	5,383	5,383	5,383	5,383	5,383	5,383	5,393	5,383
	TOTAL Const.		89,208	88,740	89,460	90,812	80,693	89,401	91,424	91,617	90,770	85,212	89,183	88,947	90,623
	TOTAL R.O.W.		19,521	19,521	19,521	19,521	25,682	20,034	17,906	18,183	20,061	19,521	19,596	19,417	19,719
	TOTAL COST		108,729	108,261	108,981	110,333	106,375	109,435	109,330	109,800	110,831	104,733	108,779	108,354	110,392
Scheme B	1	Construction	23,579	23,579	23,579	23,579	23,579	23,579	23,579	23,579	23,579	21,142	23,588	23,395	24,994
		Right of Way	2,822	2,822	2,822	2,822	2,822	2,822	2,822	2,822	2,822	2,922	2,897	2,778	3,017
	2	Construction	19,749	19,749	19,749	19,749	19,749	19,749	19,749	19,749	21,311	19,749	19,749	19,749	19,749
		Right of Way	5,946	5,946	5,946	5,946	5,946	5,946	5,946	5,946	6,496	5,946	5,946	5,946	5,946
	3	Construction	23,744	23,744	23,744	24,704	17,155	23,937	25,960	26,153	23,744	23,744	23,744	23,744	23,744
		Right of Way	2,879	2,879	2,879	2,879	*7,599	3,392	1,264	1,541	2,879	2,979	2,879	2,879	2,879
	4	Construction	20,131	19,663	20,383	20,775	18,205	20,131	20,131	20,131	20,131	20,131	20,131	20,131	20,131
		Right of Way	5,383	5,383	5,383	5,393	6,824	5,383	5,393	5,383	5,383	5.383	5,393	5,383	5,383
	TOTAL Const.		87,203	86,735	87,455	88,807	78,688	87,396	89,419	89,612	89,765	84,766	87,212	87,019	88,618
	TOTAL R.O.W.		17,030	17,030	17,030	17,030	23,191	17,543	15,415	15,692	17,570	17,030	17,105	16,996	17,225
	TOTAL COST		104,233	103,765	104,485	105,837	101,879	104,939	104,834	105,304	106,335	101,796	104,317	107,005	105,843
							SW INTERCHANGE BELOW GR. XIII								
Scheme C	1	Construction	22,928	22,928	22,928	22,928	25,234	22,928	22,928	22,928	22,928	16,834	22,903	22,666	24,342
		Right of Way	3,364	3,364	3,364	3,364	3,364	3,364	3,364	3,364	3,364	3,364	3,439	3,320	3,559
	2	Construction	18,239	18,239	18,239	18,239	23,543	18,239	18,239	18,239	19,900	18,239	18,239	18,239	18,239
		Right of Way	7,895	7,895	7,895	7,895	7,895	7,895	7,895	7,895	8,435	7,895	7,895	7,895	7,895
	3	Construction	17,155	17,155	17,155	24,590	19,039	17,349	19,917	20,111	17,155	17,155	17,155	17,155	17,155
		Right of Way	*7,599	* 7,599	*7,599	2,879	*7,599	*8,112	*6,134	*6,394	*7,599	*7,599	*7,599	*7,599	*7,599
	4	Construction	18,205	17,907	18,628	20,129	18,205	18,205	18,205	18,205	18,205	18,205	18,205	18,205	18,205
		Right of Way	6,824	6,824	6,824	5,383	6,824	6,824	6,824	6,924	6,924	6,824	6,824	6,824	6,824
	TOTAL Const.		76,527	76,229	76,950	85,876	86,021	76,721	79,289	79,483	78,088	70,433	76,502	76,265	77,941
	TOTAL R.O.W.		25,682	25,692	25,682	19,521	25,682	26,195	24,217	24,477	24,222	25,682	25,757	25,638	25,877
	TOTAL COST		102,209	101,911	102,632	105,397	111,703	102,916	103,506	103,960	102,310	96,115	102,259	101,903	103,818

				RAMPS I & 3 OMITTED XIV
S.W. Exp.	5	Construction	5,265	4,865
		Right of Way	6,231	6,231
	TOTAL COST		11,496	11,096

COST SECTIONS

1. Massachusetts Avenue to Cabot Street.
2. Cabot Street to Tavern Road and Prentiss Street to Ruggles Street.
3. Tavern Road to Brookline Avenue.
4. Brookline Avenue to Carlton Street.
5. Jackson Square to Prentiss Street.

*NOTE– Right of Way costs marked thus * include $2,600,000 for the creation of park facilities equivalent to the Fens.

In Appendix D the detailed breakdown by construction types is shown for each scheme and modification thereof.

The groupings shown in the table are those which appear to us to be most logical. However, other mixes of the same spread of modifications make many more variations available for consideration.

Where available local unit prices were used to determine unit prices where they were not available. Built up estimates were arrived at from several sources for comparison before their use.

APPENDIX "A"

INTERSTATE ROUTES 95 AND 695

CITY OF BOSTON

SOILS AND FOUNDATIONS REPORT

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I. INTRODUCTION

The soils and foundations report as part of the study of porposed Interstate Routes 695 and 95 presents the subsurface conditions which, from an engineering point of view, strongly influence the structural design and vertical alignment of the project.

This report summarizes the results of soil investigations conducted by Clarkeson Engineering Company, Inc. for the Inner Belt, from Massachusetts Avenue to Beacon Street and the Southwest Expressway, from Jackson Square to Ruggles Street.

Data from the subsurface investigation and construction experience from the Massachusetts Turnpike Extension, the Prudential Center and other structures in the Greater Boston area are also utilized in this report.

Conclusions and recommendations are developed on the basis of available data.

II. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS:

1) Soil Conditions: The Inner Belt Expressway is located in a region where bedrock is at great depth and deposits of compressible soils are predominant.

The Southwest Expressway is located in a region of shallow bedrock and glacial tills.

2) Groundwater Level: It is recommended to base the design for the Inner Belt Expressway on a minimum groundwater elevation of -5 and a maximum groundwater elevation of +8, except for the Muddy River area, where a maximum elevation of +12 is recommended.

3) Excavations: Provisions have to be made to prevent the drawdown of groundwater due to dewatering of excavations.

In some areas special steps have to be taken to prevent base failures.

4) Depressed Roadways: Hydrostatic uplift acting on these sections has to be resisted.

Over a large part of the project gravity sections are recommended, where the hydrostatic uplift is resisted by the weight of a heavy concrete slab. These sections will not be founded on piles except for limited areas of deep organic deposits.

In some areas it is feasible to resist hydrostatic uplift by tension piles.

A thickness of at least 4½' from the top of the pavement to the bottom of the concrete slab should be provided to prevent frost action.

Groundwater fluctuations around the boat section should be minimized by a system of underdrains.

Wherever feasible, bridges crossing the boat sections should be supported on these sections.

5) Architectural "T" Section: This section is sufficiently heavy to resist hydrostatic uplift. It is proposed to support the section on a floating foundation, except for an area of organic deposits where piles are recommended.

6) Viaduct Sections: Wherever compressible soils underlay the foundations it is recommended to support the viaduct sections by C.I.P. or "H" piles driven to hard layers or bedrock.

In areas of sensitive clays where viaduct foundations have to be built close to the boat sections, settlements due to remolding of the clays caused by pile driving should be prevented by predrilling.

7) Viaduct Sections Supported by Depressed Sections: Economy in foundation design can be achieved by using the weight of viaduct sections to resist buoyant forces acting on the boat sections. Such a design is proposed in an alternate scheme.

8) Embankment Sections: Embankments are feasible on the Southwest Expressway between Station 10 and Station 55.

Fill for these embankment Sections can be supplied

from excavations of the depressed roadway sections on the Inner Belt Expressway.

III. PURPOSE AND SCOPE OF STUDY

1) General Discussion: The design of the Inner Belt and Southwest Expressway, compatible with existing subsurface conditions, required a detailed subsoil exploration.

Preliminary data and previous experience indicated the probability of two basic foundation designs. One, foundations carried through the clay stratum to the hard bottom, and two, floating foundations where feasible and economically desirable in or on the clay layer.

For the first design, it was necessary to determine the characteristics of the compacted granular soil (hardpan) which underlies the clay deposit and the position of bedrock. For this purpose, 14 deep borings were drilled 10' inside the hard stratum. For the second design, it was necessary to establish the horizontal and vertical boundary of the clay and other compressible strata, their general characteristics and engineering properties. Twenty-eight exploratory drive sample borings together with seven undisturbed samples from three additional borings were obtained for this purpose.

The borings were located at the anticipated sites of major structures, and spaced approximately at 400' intervals along the entire project.

A testing program consisting of 7 consolidation tests, 3 unconfined compression tests and 2 triaxial tests was completed by two

testing laboratories.

Testing was performed in order to determine probable magnitude of consolidation settlements, skin friction values for piles and stress-strain properties of clays in the Museum of Fine Arts area where the influence of vibrations will have to be studied.

The report contains a) Pilot boring and sampling operation; b) Laboratory testing to determine physical properties of clay; c) Subsurface conditions and soil profiles; d) Study of soil features influencing foundation design; f) conclusions and recommendations.

Data collected in the subsurface exploration program and from construction experience of the Toll Road Extension and the Prudential Compound were used extensively in the foundation study presented herein.

Since both types of foundations - deep and floating - are involved in a large area, recommendations of this study will have to be corroborated by much more extensive subsurface exploration during the final design stage.

2) The Pilot Boring Program: All borings were performed by Raymond Concrete Pile Division in a period between January 27, 1965 and March 16, 1965, under the supervision of Clarkeson Engineering Company, Inc.

The pilot boring program consists of fourteen core preparatory borings, three undisturbed sample preparatory borings and twenty-eight drive sample borings.

The approximate locations of the borings are shown on location plans 2 to 9 inclusive and the individual boring logs are presented on sheets 10 to 17. To facilitate review, boring logs were plotted with reference to the roadway baselines and at their proper elevation.

The core preparatory borings were cored 10' into bedrock. Twelve of these borings were initially planned as control borings in order to obtain overall information on the depth and character of bedrock in the area and to assure penetration of the entire depth of overburden in these locations. Borings PB 36 and PB 38 were cored into rock after they could not be carried to sufficient depth as drive sample borings.

Undisturbed samples were taken in borings PB 9, PB 22X and PB 28.

Borings were taken in accordance with Section "N" of the Commonwealth of Massachusetts Department of Public Works, Specifications for Subsurface Explorations, October 24, 1963.

3) The Laboratory Testing Program: Laboratory tests were performed by two testing companies. Samples from boring PB 28 were tested by "The Thompson & Lichtner Company, Inc.", Boston, Massachusetts. Samples from boring PB 22X and PB 9 were tested by "The Haller Testing Laboratories", Plainfield, New Jersey.

Testing procedures include:

a) Classification tests (Atterberg limit, natural moisture content)

b) Consolidation Tests
c) Triaxial Tests

In every case the maximum load applied was sufficient to determine the compression index in the load range exceeding the preconsolidation load. Unloading and reloading cycles were applied at ½ ton per square foot and 2 tons per square foot.

Triaxial tests were performed on one sample of yellow clay and one sample of blue clay. A series of three tests were performed on each sample in order to determine Mohr's stress envelope. Confining pressures of 0.5, 1.0 and 1.5 ton per square foot were used.

An undisturbed sample of peat was tested to establish the feasibility of using the "Intrusion Prepakt" method to sheet excavations in the Museum area. These tests were performed by the "Prepakt Concrete Company".

All test results are presented and interpreted in the appendix, pages 48 - 61.

The results of the pilot testing program may be used with those established by the numerous tests, which were conducted recently for the previously mentioned major construction projects in the same general area.

4) Wellpoints: Five wellpoints were installed along the project and systematic ground water level observations are being conducted.

The location of the wellpoints is indicated on plan sheets 2 of 19 through 9 of 19.

Groundwater observations are tabulated in the appendix, page 47.

Tentative conclusions from groundwater observations to this date are discussed under, Section IV, Part 2).

The location of the wellpoints is indicated on plan sheets 2 of 19 through 9 of 19.

Groundwater observations are tabulated in the appendix, page 47.

Tentative conclusions from groundwater observations to this date are discussed under, Section IV, Part 2).

IV. SUBSURFACE CONDITIONS

1) Soil Conditions: The subsoil profiles of the Inner Belt and the Southwest Expressway are presented on sheets 18 of 19 and 19 of 19. These profiles were drawn by straight line interpolation between borings and should only be used for preliminary review purposes. During the design stage of the project, additional borings will be necessary to investigate specific conditions at the location of proposed foundations.

Soils were classified in accordance with engineering prpperties, rather than geologic origin. The following soil types were identified in the area of this project:

a. Man Made Fill: all the areas along the Inner Belt and the Southwest Expressway with the exception of areas in the immediate vicinity of the Muddy River and the Fens Pond are overlain by a man made fill, ranging in thickness from 6' to 24'.

Part of the fill material was transported around 1840 from Shawmut Peninsula, Dorchester and Brighton, to its present position. It is composed primarily of sand and gravel with 5 to 10 percent passing a 200 mesh screen. This material is suitable for use in the embankment sections of the project.

Some of the fill is a heterogeneous mixture of sand, silt, clay and brick.

Man made fill in this area can not be relied on to support foundation loads.

b) Organic Deposits: Organic deposits occur along the Inner Belt between Stations 31 and 44 (Roxbury Channel), Stations 49 and 58 (Roxbury Channel), Stations 78 and 129 (Muddy River and Fens Pond area) and along the Southwest Expressway between Stations 56 and 65.

These deposits consist of peats and organic silts and range in thickness from 1' to 43'. In general, the organic silts are overlain by peats.

The organic soils in this area have low shear strength and are very compressible.

The organic soils can not be relied on to support foundation loads. High organic content, (up to 10 percent), high compressibility in general, high rate of secondary compression in particular and low shear strength are responsible for the above conclusion.

c) Clays: Thick layers of clay underlie the Inner Belt from Station 10 to 25 and from Station 40 to 129 and the Southwest Expressway from Station 56 to the Inner Belt Interchange.

Two distinct horizons can be identified within the clay layer:

1. A lower horizon consists of "blue" clay. This layer reaches a thickness of 136'. It generally consists of soft or medium clays. The original color of this clay ranges from a plain gray to olive-gray.

The color designations (Yellow and Blue) are not representative, but they are now commonly used as descriptive terms used for the upper and lower layers.

2. An upper horizon of "yellow" clay, ranges in color from yellow to blue with a light yellow tinge and reaches a maximum thickness of 19', but usually its thickness is about 10'. The yellow clay layer generally consists of stiff or medium clay. It appears that the yellow clay layer developed when the clay deposits were exposed to atmospheric conditions and the upper layer consolidated by desiccation.

There is a distinct difference between the engineering properties of the blue and the yellow clay.

The yellow clay has shear strength ranging from 1,000 psf to 1,500 psf and a low compression index and can support considerable foundation pressures.

The blue clay is much weaker, having a shear strength ranging from 500 psf to 1,000 psf and a higher compression index.

The natural water content of "yellow" clay varies from 18% to 22%. Atterberg limits: PL. 20%; LL. 30%; PI. 1.5.

The natural water content of "blue" clay varies from 28% to 35%. Atterberg limits: PL. 25%; LL. 45%; PI. 1.8.

Test results on clay samples are shown in the appendix, pages 47 - 61.

Since the blue clay is overlain by a yellow clay layer, and this yellow clay in many locations is in turn overlain by a layer of compact sand and gravels (see soil profile), it is frequently possible to support spread footings or Gow caissons on top of the sand or yellow clay layer. In these cases consolidation settlements have to be analyzed.

Embankment fills or very wide foundations built over thick layers of blue clay will cause consolidation settlements over considerable periods of time and are therefore undesirable. An exception to this will be the case where the weight of the overburden removed approaches or exceeds the load applied.

d. Sands and Gravels: Sands and gravels occur mostly as glacial outwash deposits, and locally as alluvial deposits.

Thick layers of sands and gravels occur on the Inner Belt between Stations 21 and 58, and between Stations 100 and 122 where they are overlain by blue clay, and on the Southwest Expressway between Stations 45 and 60.

In some locations a "crust" of compact sands and gravels overlays layers of yellow or blue clays. (Inner Belt Stations 58 to 75, Stations 120 to 130.)

Deposits of sands and gravels are usually firm or medium, however some local deposits of loose sands were encountered.

Sands and gravel will give safe support to spread footings wherever they are not underlain by weaker soils. They will provide excellent material for embankment fill.

e. Glacial Tills and Drift: Ground moraine deposits of glacial tills occur on the Southwest Expressway between Stations 14 and 52 where characteristically the depth to bedrock is shallow. Glacial tills and drift also occur on the Inner Belt together with the deep sand and gravel deposits mentioned before.

Glacial tills and drifts are a mixture of silts, sands, gravels, clays and boulders. In this area they range in composition from boulder clays to predominantly granular soils. Boulder clay, however, was only encountered in isolated locations (Southwest Expressway, Stations 14 to 16).

Glacial tills will safely support spread footings. Most of the glacial tills will provide good material for embankment fill.

f. Very Compact Silts, Sands, Gravels and Gracial Tills (hardpan): This type of soils can not be easily distinguished from similar soils in a less compact state. However they are identified in this report because characteristically, a layer of this material, varying in thickness from several feet to 80 feet covers the bedrock surface.

It may be assumed that, while steel H piles driven to refusal are likely to penetrate this very compact layer and bear on bedrock, closed end pipe piles will penetrate it only to a very shallow depth.

g. Bedrock: The two rock types most frequently encountered on this project are Roxbury conglomerate and Cambridge argillite. The rockcores indicate that in some locations the bedrock surface is overlain by a layer of boulders.

Rockcores taken on this project are identified in the appendix.

2) Groundwater Conditions: Groundwater level observations to this date in wellpoints 1 through 5 are tabulated in the appendix, page 47.

These wellpoints were located to provide information on the conditions in the project area:

WP 1 and WP 2 are located at greater distances from the main bodies of water. WP 3 is located in the Fens Pond area, WP 4 is located in the Muddy River area and WP 5 in the area of the Southwest Expressway.

Observations were conducted during a short period of time and are therefore inconclusive. However, it appears that in wellpoints WP 1, and WP 3 groundwater levels seem to be lower than the elevation of the great bodies of water controlling these levels. This may be attributed to drawdown caused by sewerage, basements and dewatered excavations.

Wellpoint WP 4 indicated groundwater elevations which correspond to or exceed the water elevation in the Charles River Basin.

Wellpoint WP 5 indicates consistently groundwater elevation higher than the water level of Charles River Basin.

The following preliminary assumptions about ground-water elevations are proposed. During the design stage of the project these assumptions will have to be carefully reviewed and revised:

Inner Belt Stations 10 to 115 Minimum W.L. -5 Maximum W.L. +8

Inner Belt Stations 115 to 135 Minimum W.L. -5 Maximum W.L. +12

V. FOUNDATION STUDY:

1) Consolidation Settlements: Because of the importance of differential settlements the volume compressibility clays will be discussed herein separately. The results will be applied to the project, wherever such conditions exist.

Clay: The consistency of the clay starting at the surface gradually decreased from stiff to firm to soft as the depth increases to a certain level. Where upon, the consistency gradually reverts to stiff as the depth progresses to the bottom of the stratum. Because of this condition the methods of simplifying the problem of estimating settlements, as present by Arthur and Leo Casagrande in their foundation report for the Prudentail Center is presented herein. (Foundation Investigation for Prudential Center in Boston - Volume I by Arthur and Leo Casagrande - Pierce Hall - Cambridge, Massachusetts, March 1958).

By estimating the settlement layer by layer based on a mean value of a series of test results, one may arrive at an influence value, as a function of a selected load (constant). Applying this influence value to any part of the project for soil bearing or pile foundations the settlement can be readily estimated without appreciable error.

These influence values, derived from the attached test report are presented hereafter:

SAMPLE	ELEVATION	$\bar{e}$	$\bar{p}$ ton/sf	C	H in feet	ΔH in inches
PB-22X	-10 to -20	0.965	1.0	.06	10	.15
PB-28	-20 to -30	0.488	1.5	.04	10	.10
PB-28	-40 to -50	0.730	1.8	.07	10	.15
PB-22X	-50 to -60	0.720	2.0	.12	10	.16
PB-9	-70 to -80	0.89	3.0	2.0	10	2.0

Elevation Based on U.S.G.S. Data

Glossary of Terms:

C = C (compression index)

$\bar{e}$ = in situ void ratio

$\bar{p}$ = present overburden pressure

Δp = applied net increase in stress which in this analysis is assumed to be a uniform stress of 0.1 ton/sf

H = thickness of layer

Δ H = decrease in thickness of layer of thickness H (used as influence value)

SAMPLE	ELEVATION	$\bar{e}$	$\bar{p}$ ton/sf	C	H in feet	Δ H in inches
PB-22X	-10 to -20	0.965	1.0	.06	10	.15
PB-28	-20 to -30	0.488	1.5	.04	10	.10
PB-28	-40 to -50	0.730	1.8	.07	10	.15
PB-22X	-50 to -60	0.720	2.0	.12	10	.16
PB-9	-70 to -80	0.89	3.0	2.0	10	2.0

Elevation Based on U.S.G.S. Data

Glossary of Terms:

C = C (compression index)

$\bar{e}$ = in situ void ratio

$\bar{p}$ = present overburden pressure

Δp = applied net increase in stress which in this analysis is assumed to be a uniform stress of 0.1 ton/sf

H = thickness of layer

Δ H = decrease in thickness of layer of thickness H (used as influence value)

The above derived values are consistent with the large scale investigations mentioned previously.

When no test data are available at a certain location use of the influence value according to the depth (elevation) is more realistic than using the standard penetration to select the influence value.

Estimating the time of settlement based on coefficients of consolidations does not yield dependable results and more often is responsible for serious consequences. The time of settlement may be predicted based on definite experience on similar structures founded on similar soil conditions.

In addition to the amount of settlement due to the applied load (soil bearing or pile foundation) there are several other factors which will contribute to the settlement at this area.

a. Settlement due to remolding the clay stratum by pile driving:

Careful consideration should be given to select a type of pile which has the least displacement. Closed end pipe piles or cast in place piles are considered as full displacement piles. The H pile compared to the above mentioned piles - at least theoretically - cause less of a volume displacement. Open end pipe or Cobi piles and pre-bored piles or caissons are the most suitable.

At the present time, no sufficient data are available to estimate the magnitude of settlements that would develop due to the reconsolidation of clay caused by pile driving.

As an example, around the John Hancock Building one may notice the unusually large settlement of the sidewalk which was proved to be the direct result of the disturbing of the clay stratum, by driving a large number of H piles to bedrock.

Another example is the garage floor, floating on a sand layer under the Prudential Tower, which has a larger settlement in the vicinity of an adjacent structure which rests on closed end pipe piles. The settlement will form a depression around the perimeter of the pile foundation to a maximum distance of about 100 to 150 feet from the perimeter of the pile foundation.

b. Rebound: A reliable basis of predicting settlement is from observations made during construction of other large structures resting on similar soil conditions, such as the Toll Road Extension, the Prudential Center, the New England Mutual Life Insurance Building, etc. Such observations indicate that it would be in direct proportion to the depth of excavation, with a magnitude of 1/2" to 3/4" per 10' of excavation.

Test reports presented in the appendix indicate that the amount of swelling per 10' of excavation would be the same as mentioned above over an estimated period of time of two months.

In each case a large percentage of the settlement was eliminated by using a method of preconsolidation. (Surcharge)

The measures taken to minimize the settlement in this project will be mentioned at the section where such a problem arises.

2) EXCAVATION

a) Dewatering and Recharge: A wellpoint system would probably have to be used for dewatering purposes. Similar systems have been used successfully in other Boston sites for similar projects.

One stage or several stages may have to be used. In areas where clays are overlain by a sand layer dewatering of the sand layer would be very effective. However, in connection with the pumping of groundwater from the Prudential excavation it was pointed out that the organic layer formed a horizontal barrier in some areas keeping the upper water table apparently uneffected by pumping, while groundwater levels in other sections on the site responded immediately. (Donald G. Ball, Prudential Center Foundation tour, Boston Society of Civil Engineers. Vol. 49; No. 3; July 1962)

The fill overlying the harbor mud or stiff clay unfortunately in many locations has a critical grain size (D) D = 0.2mm. which means that the drawdown would be felt at least a distance of 500' from the pumping site. For example dewatering a trench 10' below water table for a sewer layout at Dalton Street immediately lowered the free water table along Massachusetts Avenue.

If however D = .003mm. the effect of pumping would be only felt to a distance of 20 to 40 feet from the excavation.

The physico-chemical effect of lowering the free water table - as a consequence of dewatering a large area - presents a

well know problem not only from a technical point of view but also from a legal point of view.

One or several of the following measures, depending on local conditions may be used to alleviate this problem:

a. Deep Sheetpiling
b. Backfeeding of Sufficient Water
c. Using a Trench Filled with Compacted Silt
d. Using a Trench Filled with Bentonite Slurry

a. Deep Sheeting: In locations where deep excavations are planned in granular soils, which have a high permeability, sheetpiling may have to be extended to a considerable depth below the bottom of the excavation in order to reduce the rate of percolation and to prevent piping.

b. Backfeeding: In using backfeeding with a wellpoint system, the volume and the pressure of the water should be higher than required for the pumping operation. For this reason an outside supply of water may be necessary for backfeeding.

Based on the experience gained from the Prudential excavation the water should be recharged to the same soil stratum from which it was pumped.

c. Trench with Compacted Silt: On both sides of the depressed section trenches would be excavated down to the underlying organic or clay layer and the trenches would be backfilled with a compacted silt and/or clay. The non plastic organic sandy silt which was described as unsuitable material in section IV-1 may be quite suitable for this purpose. The critical grain size of the organic silt is approximately equal to .003mm.

d. Slurry Trenches: Trenches as described above backfilled with bentonite clay slurry. (Cronese - terminal Engineer Contractors 2975 Wilshire Blvd., Los Angeles, California.)

The above mentioned trench methods also greatly reduce the volume of pumping.

b) Stability: Since the bottom of most excavations will rest on soft or medium blue clay, these excavations may fail by heaving of the bottom. Such failures would not only endanger the work performed but may also be detrimental to adjacent structures.

Wherever the yellow clay layer overlays the soft blue clay, the severity of the problem is reduced since the high shear strength of this material will contribute to the stability of the excavation.

The problem is particularly severe in some areas of organic deposits, where the yellow clay layer is absent because of past erosion and soft blue clay is directly overlain by marine silt, with only a thin layer of sand intervening. In this case we can not rely on friction resistance above the bottom of the excavation and the stability would solely depend on the bearing capacity of the soft clay. If we can assume a minimum bearing capacity $p = 5.7c$, and $c = \pm 750$ psf for blue clay, and we further assume the saturated weight of the overburden to be 140 pcf, we arrive at the following maximum safe excavation depths:

D = 20' at a factor of safety of 1.5
D = 15' at a factor of safety of 2

where:
p = allowable bearing pressure in psf
c = cohesion in psf
D = depth of excavation in feet

This, however, represents an extreme case.

Heaving could be prevented by driving the sheetpiling to a greater depth, however we should keep in mind that the shear strength of the Boston blue clays tends to decrease with increasing depth.

c) Rebound: Rebound occuring at the bottom of excavations will be greatest in the center and smaller along the edges of excavations.

In accordance with data from other locations in the Boston area which have conditions similar to those encountered on the Inner Belt rebound should be expected to be roughly proportional to the depth of excavation. Rebound increments ranging from 1/2" to 3/4" should be expected for every 10' depth of excavation. (See section V-1) If subsequently applied structural loads will not exceed the weight of the overburden removed, consolidation settlements should not significantly exceed the rebound.

3) DEPRESSED ROADWAYS

Depressed roadway sections are considered along the entire length of the Inner Belt and on several ramps. The depth of these sections varies. Foundation problems that will be encountered in the construction and support of the depressed roadways are discussed hereafter.

a) Buoyancy: Extreme groundwater conditions assumed for this study were discussed in Section IV-2. Under these conditions buoyancy will be the most significant factor in the design of the structures that will support depressed roadways. Since these structures will be deeply submerged below ground water level, they will have to float in the groundwater. The term "boat sections" was therefore adopted for these structures. Boat sections will be designed as monolithic structures and waterproofed around their perimeter. The upward reaction of the buoyant force on the boat sections can be resisted in two ways:

1. Gravity Sections: It is proposed to provide weight by a thick concrete slab at the bottom of the boat section and by a layer of gravel over the concrete slab. The proposed gravel layer has several advantages: It provides cheap ballast, it reduces the thickness of the concrete slab which presents difficult construction problems, and it will pervent adverse effects on the pavement by groundwater percolation through the slabs or through joints. This groundwater percolation may eventually occur in spite of the waterproofing because of the high pressure differential across this slab.

2. Tension Piles: It is safe to assume that the blue and yellow clays which underlie most of the Inner Belt will develop certain shear stresses by skin friction along the surface area of piles.

The use of tension piles is therefore feasible as an alternate solution wherever soil conditions permit and should be considered where the boat section is very deep. The following types of piles are considered:

Pealed Woodpiles: Under ordinary conditions a mechanical anchor should be provided to transmit tension from the piles to the slab.

C.I.P. Piles: (Closed end pipe or "prepakt concrete") wherever intervening sand or peat layers will require excessive pile length or will make the driving of woodpiles risky.

On a tentative basis the following design criteria are proposed:

Skin Friction Values:

Yellow Clay: C = 450 psf
Blue Clay: C = 250 psf
All Other Soils C = 0

Group Action: The buoyant force to be resisted is not to exceed 25% of the buoyant weight of the volume of soil + the piles enclosed within the limits of the pile group.

Pile Testing: Special pull-out tests to be devised. Total allowable uplift on pile not to exceed 1/4 of maximum tension based on test.

Maximum Pile Load: The maximum allowable pile load

in tension not to exceed 1/2 of the maximum load allowed for the same pile in bearing.

These criteria provide for a factor of safety N = 4. It is proposed to apply these criteria to an assumed groundwater elevation of +3. If higher elevations should occur during short periods of time, the large factor of safety will prevent failure.

Feasibility of Tension Piles on the Inner Belt: In the following locations tension piles are not feasible:

Stations 23 - 43
Stations 65 - 68
Stations 118-122
Stations 130-135

In all other locations tension piles are feasible in one form or another.

b) Frost Action: Since the width of the boat section is very great the influence of frost action has to be taken into consideration. The depth of frost penetration is a function of the freezing index at the excavation in question. For the Greater Boston area a 700 degree day* may be used for design purposes. A total pavement, sub-base and concrete thickness of 4½ feet provides adequate frost protection.

c) Construction Loads: During construction, and the period of dewatering, the depressed section is subject to full design load where the subsoil has not the required allowable bearing capacity to support the boat section.Under these conditions pile foundations have been selected.

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*limell, K. A. "Frost Action and Permofrost, Section 13, Highway Engineering Handbook. McGraw Hill, 1960.

d) Regions of Deep Organic Deposits: Several regions of deep organic deposits occur along the Inner Belt. The possibility of founding even a "weightless" section on these deposits is ruled out. There are two ways in which these areas could be handled:

1. Organic deposits could be mucked and replaced by gravel.
2. Piles, driven through these deposits could support the boat section.

In the case of deep deposits alternate (2) seems to be more economical. In this case piles could be driven to a sufficient depth into clay and also act as tension piles.

An exception to this is the organic deposits between Stations 31 and 44 on the Inner Belt which are underlain by granular soils. In this particular case a "gravity" section will have to be supported on C.I.P. piles.

e) Fluctuations in Groundwater Level: If the extreme conditions suggested in Section IV-2 ever occur, groundwater level fluctuations would amount to a maximum of 17'. However in reality it appears that these fluctuations do not exceed 10', although larger fluctuations may occur as momentary peaks.

Under prevailing condition groundwater fluctuations of 10' could cause uplift or settlements of approximately 1/4" to 1/2" in gravity boat sections, provided enough time is available for swelling or consolidation settlement. In reality it appears that the time lag or settlements or

swelling due to the low permeability of clays will have a damping effect on these movements.

Movements of this order of magnitude should be tolerable, but problems may still arise. The effect of groundwater fluctuations on sections founded on tension piles should be insignificant.

f) Underdrainage: It is proposed to surround these sections by a 2' thick blanket of gravel and install underdrains at elevations + 2.5 or 3.0. If impervious fill will be used to cover these underdrains there is a good chance that the effect of the peak of major storms will not substantially increase the hydrostatic uplift of these structures.

Serious consideration should be given to the possibility, in certain areas, to create a system of underdrains that will enable us to design for lower maximum groundwater elevations than these proposed in Section IV-2.

4) ARCHITECTURAL "T" SECTION

From Huntington Avenue to Brookline Avenue each roadway is depressed but separated by a "T" structure for asthetics.

Based on the present information on subsurface conditions a floating foundation is considered to be most suitable. While the boat sections are buoyant, this section will have a resultant downward reaction of approximately 1.5 ksf at a groundwater level of + 3. This reaction would increase to 2 ksf at the minimum groundwater elevation propsed in Section IV-2 and to 3 ksf during construction.

According to conditions encountered in the borings most of the structure would extend below the bottom of yellow clay and have to be supported on blue clay.

The applied structural loads after completion of construction are less than the weight of overburden removed by excavation.

The consolidation settlements should not exceed the amount of rebound which is estimated at ± 1½" in a construction period of two to three months. These settlements are judged as tolerable since the differential settlement is assumed not to exceed ½ of the total settlement. It therefore appears that a floating foundation is feasible. Careful subsurface investigations should be conducted to corroborate these conclusions.

Between Stations 98 and 112 organic deposits underlie the structure. In these locations the structure will have to be supported on piles.

5) BRIDGES CROSSING OVER THE BOAT SECTIONS

Where bridges cross over the boat section the weight of these structures can be used to resist buoyancy.

It is therefore proposed to support these bridges on the boat sections.

The combined weight of the structure in this case is not likely to exceed the weight of overburden removed by excavation. These structures could be supported directly on underlaying soil, or, in the case of soft clays or organic materials, wooden or CIP piles may be used to support the structures.

In the locations where this is not possible, for example a long span required to cross the boat section. It is desirable to place the support as close as possible to the depressed section. In order to minimize effects of disturbance of the subsoil (clay) by pile driving, it is recommended that in these cases piles be installed in pre-drilled holes.

6) VIADUCT SECTIONS

In many locations along the Inner Belt and the interchange area blue clay is overlain by layers of yellow clay and a "crust" of compact sands and gravels. Ordinarily foundations can be supported by these layers. Since pressures due to isolated footings will dissipate rapidly with depth, consolidation settlements of such footings will be of a tolerable magnitude.

In the case of the proposed viaduct section, 100' long continuous spans will be supported by the piers. The proposed pier footings therefore have to resist heavy foundation loads. (3,200 kips vertical, 3,300 foot kips longitudinal moment, 6,600 foot kips transverse moment).

Because of the continuity of the spans it is also necessary to prevent settlements.

In order to enable us to support these piers on spread footings the following conditions have to be met:

1. Allowable bearing pressures have to be 4 tsf or more.
2. No significant settlements can be tolerated.

These conditions can not normally be met on layers that overlay deep deposits of soft to medium clay. It is therefore recommended to use spread footings only in areas that are not underlain by these clays.

Wooden piles should be ruled out for similar reasons, since foundations of excessive size would be necessary to accomodate the required number of piles.

For the above mentioned reasons C.I.P. or H piles will be required to support most of the piers of the proposed viaduct section. These piles would reach refusal in the firm layers overlaying bedrock or on bedrock.

C.I.P. (closed end pipe) piles are likely to reach refusal after slight penetration of the very compact sand and gravel layers overlaying bedrock. H piles are more likely to penetrate to bedrock.

It is believed that under prevailing conditions C.I.P. piles may be a more economical solution that is equally satisfactory. This is particularly true for the viaduct for Riverway relocation where the clay layer is not very deep and is underlain by deposits of granular soils of considerable depth.

Heavy structures in the area of the Southwest Expressway up to Station 55 ± where granular soils and tills cover most of the area will be probably supported by spread footings.

A special situation exists on the Inner Belt between Station 10 and 25 and Station 42 and 50.

The depressed section and the elevated section are parallel and adjacent to each other. Each exerts its' influence on the other foundation. A normal driven pile foundation will tend to disturb

the clay under the depressed section and may cause settlements even if the depressed highway exerts no foundation loads. (Refer to Section V-1)

If further soil investigations in the final design show that the clays are sensitive, the preboring for each pile may be necessary. The type of pile placed in the prebored hole may be selected as "H" pile or close end pipe pile.

From Station 50 to 85 the two roadways are separated and the above mentioned problem is eliminated, except where viaduct sections pass within approximately 40' of any important structure (as existing bridge foundations or existing buildings).

At the transition area, where the divided highway changes to depressed (Parker Street area) and embankment section may be used. Seven feet is considered as the limiting height of such an embankment.

7) VIADUCT SECTIONS SUPPORTED BY BOAT SECTIONS

An economical foundation design can be achieved by building the viaduct section over the boat section. In this case the weight of the viaduct will help to resist buoyancy. Several foundation schemes are possible. Each of these schemes has advantages under different conditions and the ultimate choice of the proper design will probably depend on the depth of the boat section and on soil conditions. The following schemes are possible:

Scheme 1: The viaduct section will be founded on pier bents spaced approximately at 70' and supported by piles designed for the foundation load applied by the viaduct without regard to the uplift applied by the boat section.

65' long sections of the boat will then be keyed into these pier footings. Hydrostatic uplift will push these boat sections against the pier footings. The bottom of these boat sections being 65' long and 60' wide and supported on two sides by the piers and on two sides by the sidewalls will act as a two-way slab permitting a rather thin concrete floor.

The viaduct, including the piers, weighs about 32 kips per linear foot. If the capacity of the piles to resist uplift is taken into account, it can be assumed that on the average this viaduct section will be capable of resisting an uplift force of 40 kips per linear foot.

On a 60' wide boat section this will correspond to a hydrostatic head of 11'.

Assuming that no tension piles are used and the maximum groundwater level is + 8, the boat section will have to be "weightless" at groundwater elevation - 3. At the minimum groundwater elevation of - 5 the pile foundations of the piers will be slightly overstressed, but within permissible limits. This will permit to build a boat section of considerable depth, using only the concrete thickness necessary to resist the moments. If boat sections of greater depth should be required the weight of the concrete slab would have to be increased.

This scheme has the great advantage of a foundation that will not settle.

Compared with the gravity boat section, the concrete saved will equal in weight to 40 kips per linear foot, or approximately 10 cubic yards per linear foot. Compared with the tension pile section the savings will be substantially less.

Scheme 2: Boat and viaduct rest on a common, continuous footing supported by wooden piles. These piles will act in tension at maximum groundwater level, and as bearing piles at minimum groundwater level.

The saving achieved by this scheme will be:

1. Elimination of piles necessary to support the viaduct.
2. Reduction of the number of tension piles in the boat section.

This scheme will have the disadvantage of high pile loading during construction, however the problem can be avoided by stage construction. The scheme will be particularly advantageous for deep boat sections.

Scheme 3: Similar to scheme 2, but without piles. This scheme will be advantageous if the depth of the boat section is not too great, so that no gravity concrete has to be used.

It has the disadvantage of being subject to settlements if soil conditions are not favorable.

The selection of the proper scheme will largely depend on conditions. No scheme is therefore recommended as more desirable than other schemes, however, scheme 1 appears to be the most conservative one.

8) EMBANKMENT SECTIONS

Due to the good subsurface condition and the cost advantage the use of an embankment was given careful consideration in the design of the Southwest Expressway.

According to the boring information the man made fill does not exceed 10' in thickness in this area. The fill has remained for more than 100 years in its present location, and over a long period of time has been subjected to different static and vibratory loading. The fill does not overlie any compressible stratum.

From the above facts it may be stated that the present fill is capable of holding 25' of embankment without any long term settlement which might cause a delay in the construction.

To eliminate differential settlement and the consequence of drag forces exerted by a settling embankment adjacent to structures it is proposed that the fill section be terminated at Station 55 + 0 for the Southwest Expressway and the adjacent Ramps and Connectors.

All structures (Bridges, Retaining Walls, etc.) from Station 10 + 00 to Station 55 + 00 may be on soil bearing foundations not to exceed the bearing capacity of the foundation layer as determined by the Boston Building Code and A.A.S.H.O. Specifications.

Fill for the embankment section will be available from excavations of the Inner Belt depressed sections.

9) PROPOSED 20' DIAMETER MUDDY RIVER TUNNEL: Boring logs in the area indicate that for more than 60% of its length the tunnel will have to be advanced through compact sands and gravels. The downstream part of the tunnel will penetrate soft blue clay.

These conditions will make tunneling more difficult than in clay layers. However the danger of damaging effects of differential settlements due to the construction of the "T" section only exists at the downstream end of the tunnel.

APPENDIX

to

SOILS AND FOUNDATIONS REPORT

COMP. BY
CHECK BY
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 1 OF
DATE
LOCATION

SUBJECT BORINGS

BORING NO.		STATION		OFFSET	DEPTH
P.B. 1G	I. BELT	16+60	N.B.	15' LT.	100'
" 2	"	21+30	"	5' LT.	97'
" 3	"	26+05	"	45' LT.	166'
" 4	"	31+00	"	15' RT	84'
" 5	"	34+80	"	10' RT.	139'
" 6A	"	38+60	"	30' LT.	122'
" 7	"	44+10	"	40' LT.	154'
" 8	"	49+10	"	℄	113'
" 9	"	54+40	"	140' LT.	122'
" 10	"	57+75	"	105' LT.	161'
" 11	"	60+10	"	110' LT.	145'
" 12B	"	64+20	"	150' LT.	155'
" 13	I. BELT	65+65	N.B.	420' LT.	129'
" 13	CONN. A	65A+60		20' RT.	129'
" 14	CONN. A	63A+10		50' RT.	92'
" 15	CONN. D	60D+20		220' RT.	86'
" 16	CONN. D	62D+50		290' RT.	147'
" 16	I. BELT	71+00	N.B.	360' LT.	147'
" 17	I. BELT	71+60	N.B.	100' LT.	85'
" 18	CONN. D	61D+85		15' LT.	136'
" 19	I. BELT	75+05	N.B.	90' LT.	126'
" 20	"	78+20	"	290' LT.	85'
P.B. 21	I. BELT	81+70	N.B.	40' RT.	174'

COMP. BY
CHECK BY
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 2 OF
DATE
LOCATION

SUBJECT BORINGS (CONT.)

BORING NO.	STATION			OFFSET	DEPTH
P.B. 22	I. BELT	86+65	N.B.	150'LT.	160'
" 22X	"	88+45	"	60'RT.	165'
" 23	"	92+55	"	60'RT.	201'
" 23X	"	90+55	"	130'LT.	31'
" 24	"	90+70	"	150'RT.	86'
" 25	"	97+05	"	75'LT.	180'
" 26	"	100+30	"	5'RT.	85'
" 27	"	102+90	"	105'RT.	190'
" 28	"	105+90	"	10'LT.	135'
" 29	"	109+85	"	65'RT.	36'
" 30	"	114+00	"	10'LT.	124'
" 30X	"	117+00	"	40'RT.	103'
" 31A	"	120+30	"	80'LT.	48'
" 32	"	123+85	"	45'LT.	99'
" 33	"	129+05	"	60'LT.	76'
" 34	I. BELT	134+30	N.B.	20'LT.	153'
" 35	CONN. A	56A+45		90'LT.	64'
" 36B	CONN. A	52A+35		40'LT.	49'
" 37	S.W. EXP.	45+65		125'RT.	24'
" 38C	" "	41+30		300'LT.	37'
" 39B	" "	40+35		160'RT.	34'
" 40A	" "	34+85		50'RT.	51'
P.B. 41C	S.W. EXP.	30+20		40'RT.	47'

COMP. BY
CHECK BY
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 3 OF
DATE
LOCATION

SUBJECT BORINGS (CONT.)

BORING NO.	STATION	OFFSET	DEPTH
P.B. 42	S.W. EXP. 25+75	120' RT.	87'
" 43	" " 21+10	65' RT.	80'
" 44	" " 15+65	30' LT.	41'
" 45	S.W. EXP. 13+60	40' LT.	31'
W.P. 1	I. BELT 34+45 N.B.	65' RT.	
" 2	" 65+55 "	30' RT.	
" 3	" 88+60 "	100' RT.	
" 4	I. BELT 126+30 N.B.	110' LT.	
" 5	CONN. A 56A+75	25' LT.	

NOTE:

P.B. = PILOT BORING
W.P. = WELL POINT

COMP. BY
CHECK BY
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

DATE
LOCATION

SUBJECT

IDENTIFICATION		ATTERBERG LIMIT			UNCONFINED COMPRESSION TEST - SHEAR STRENG. - KFS					TRIAXIAL COMP. TEST (Undrained) KFS.			STD. PENETRATION	REMARK DESCRIPTION
Nº	Depth ft.	LL.	PL.	PI.	ULT.	PEAK VALUE	PRE. CONS.	C_v	w %	φ	C	S	N	
PB-28	-32	30	19		2.46	3.94			20.5				17	Stiff Blue Clay
	-52	45	27		1.20	1.35			30.2				8	Medium Blue Clay
	-72	48	27		0.93	1.19			35.4				5	do
PB 22U	26									15° 28° 41°		4 2 1		Stiff Blue Clay varved
	38									29°		0.5		Gray clay varved

COMP. BY
CHECK BY
ACTIV. NO.

SHEET OF
DATE
LOCATION

SUBJECT

Nº of BORING	Ground EL.	Ledge EL.	Vertical Penetration In.	Recovery		Rate of coring ft/min.	Description of Core - Rock	Remark
				In.	%			
PB-3	+10.8	-155.3	180	14	8		Cambridge ARGILLIT	
PB-5	+16.6	-131.7	144	14	10		BASALT	
PB-7	+14.8	-137.5	156	9	6		Andover GRANIT	Probably Boulder
PB-10	+13.0	-146.0	120	20	17		Probably BOULDERS	Basalt and Granit.
PB-16	+11.5	-135	120	19	16		do	do
PB-27	+10.7	-179.3	300	103	34		Cambridge ARGLLIT	soft
PB-23	+12.7	-188.3	156	17	11		BASALT	
PB-30	+18.7	-148	180	48	27		Cambridge ARGILITE	Slatey caracteristique
PB-34	+13.7	-139.3	120	12	10			
PB-36	+21.5	-27.5	120	101	84	.30	Cambridge ARGILITE Roxbury CONGLOMERATE	
PB-38$_c$	+24.7	+12.7	120	14	12		Roxbury CONGLOMERATE	
PB-39$_B$	+32.3	-1.7	180	12	7		do	
PB-42	+50.0	+36.5	120	12	10		do	
PB-44	+27.4	-13.6	120	18	15		HARD TILL Roxbury CONGLOMERATE	

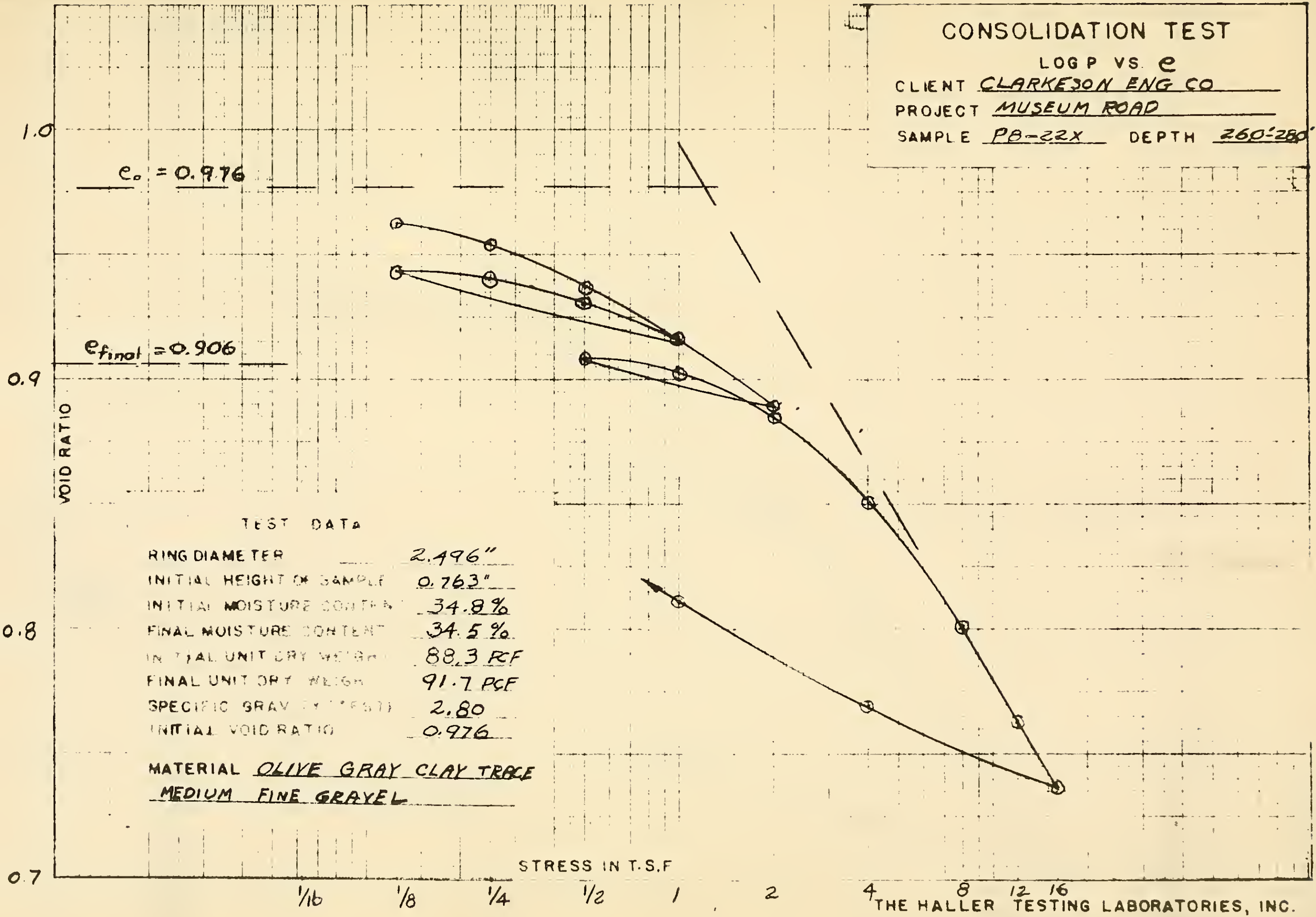
GROUNDWATER OBSERVATIONS

WELLPOINT NO.	Groundwater Level (U.S.G.S. Datum)			
	3-12-65	3-29-65	4-5-65	4-12-65
WP1	0.22	-0.67	-0.23	-0.33
WP2	3.99	-----	-----	-----
WP3	-0.20	-0.51	-1.16	-1.26
WP4	5.41	2.85	2.40	2.30
WP5	5.16	4.05	3.90	3.65

CONSOLIDATION TEST

LOG P VS. e

CLIENT CLARKESON ENG CO
PROJECT MUSEUM ROAD
SAMPLE PB-22X DEPTH 260'-280'



TEST DATA

RING DIAMETER	2.496"
INITIAL HEIGHT OF SAMPLE	0.763"
INITIAL MOISTURE CONTENT	34.8%
FINAL MOISTURE CONTENT	34.5%
INITIAL UNIT DRY WEIGHT	88.3 PCF
FINAL UNIT DRY WEIGHT	91.7 PCF
SPECIFIC GRAVITY (TEST)	2.80
INITIAL VOID RATIO	0.976

MATERIAL OLIVE GRAY CLAY TRACE MEDIUM FINE GRAVEL

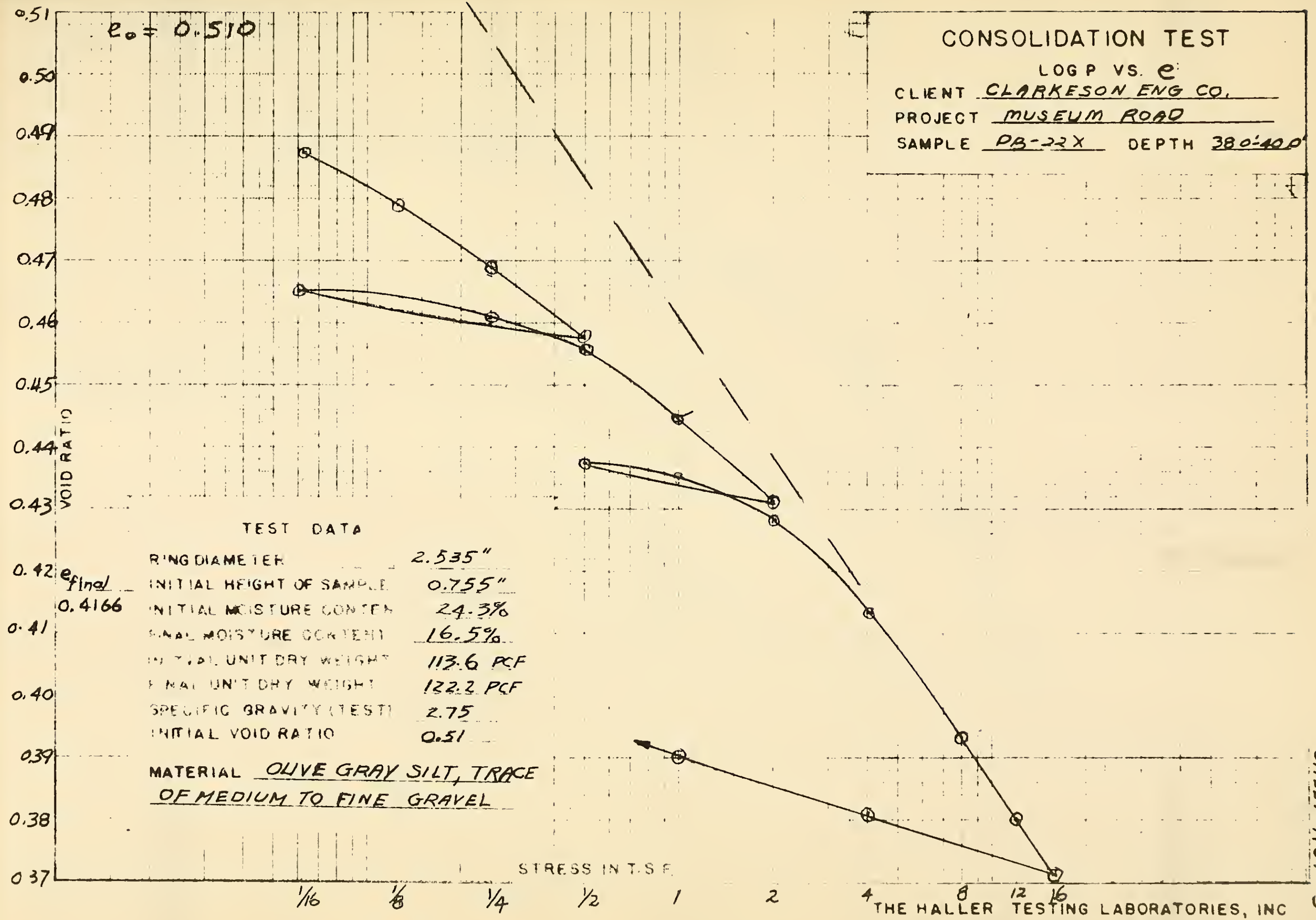
THE HALLER TESTING LABORATORIES, INC.

SHEET NO. 5

CONSOLIDATION TEST

LOG P VS. e

CLIENT CLARKESON ENG CO.
PROJECT MUSEUM ROAD
SAMPLE PB-22X DEPTH 38.0'-40.0'



TEST DATA

RING DIAMETER	2.535"
INITIAL HEIGHT OF SAMPLE	0.755"
INITIAL MOISTURE CONTENT	24.3%
FINAL MOISTURE CONTENT	16.5%
INITIAL UNIT DRY WEIGHT	113.6 PCF
FINAL UNIT DRY WEIGHT	122.2 PCF
SPECIFIC GRAVITY (TEST)	2.75
INITIAL VOID RATIO	0.51

MATERIAL OLIVE GRAY SILT, TRACE OF MEDIUM TO FINE GRAVEL

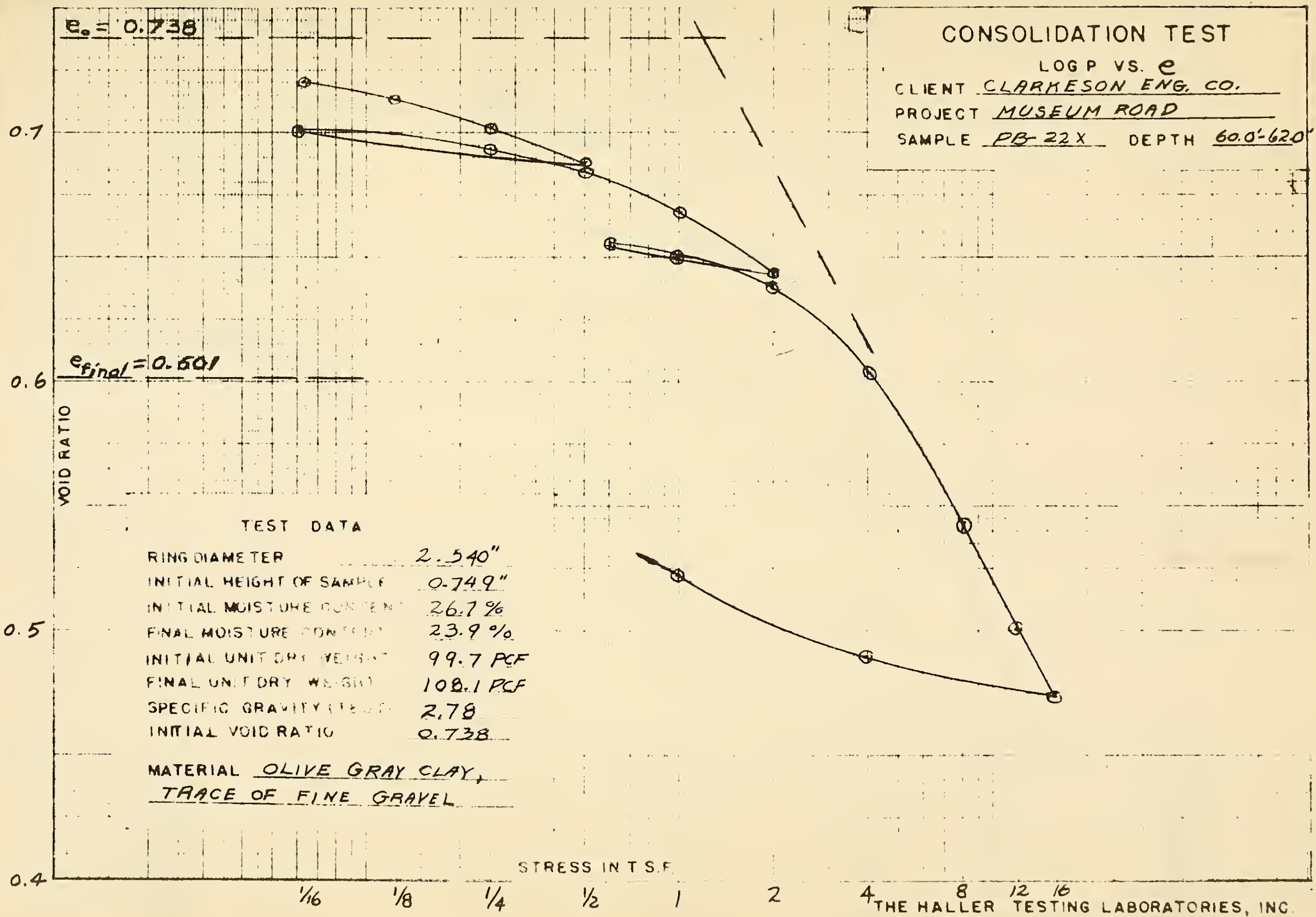
THE HALLER TESTING LABORATORIES, INC

SHEET NO. 9

CONSOLIDATION TEST

LOG P VS. e

CLIENT CLARKESON ENG. CO.
PROJECT MUSEUM ROAD
SAMPLE PB-22X DEPTH 60.0'-62.0'

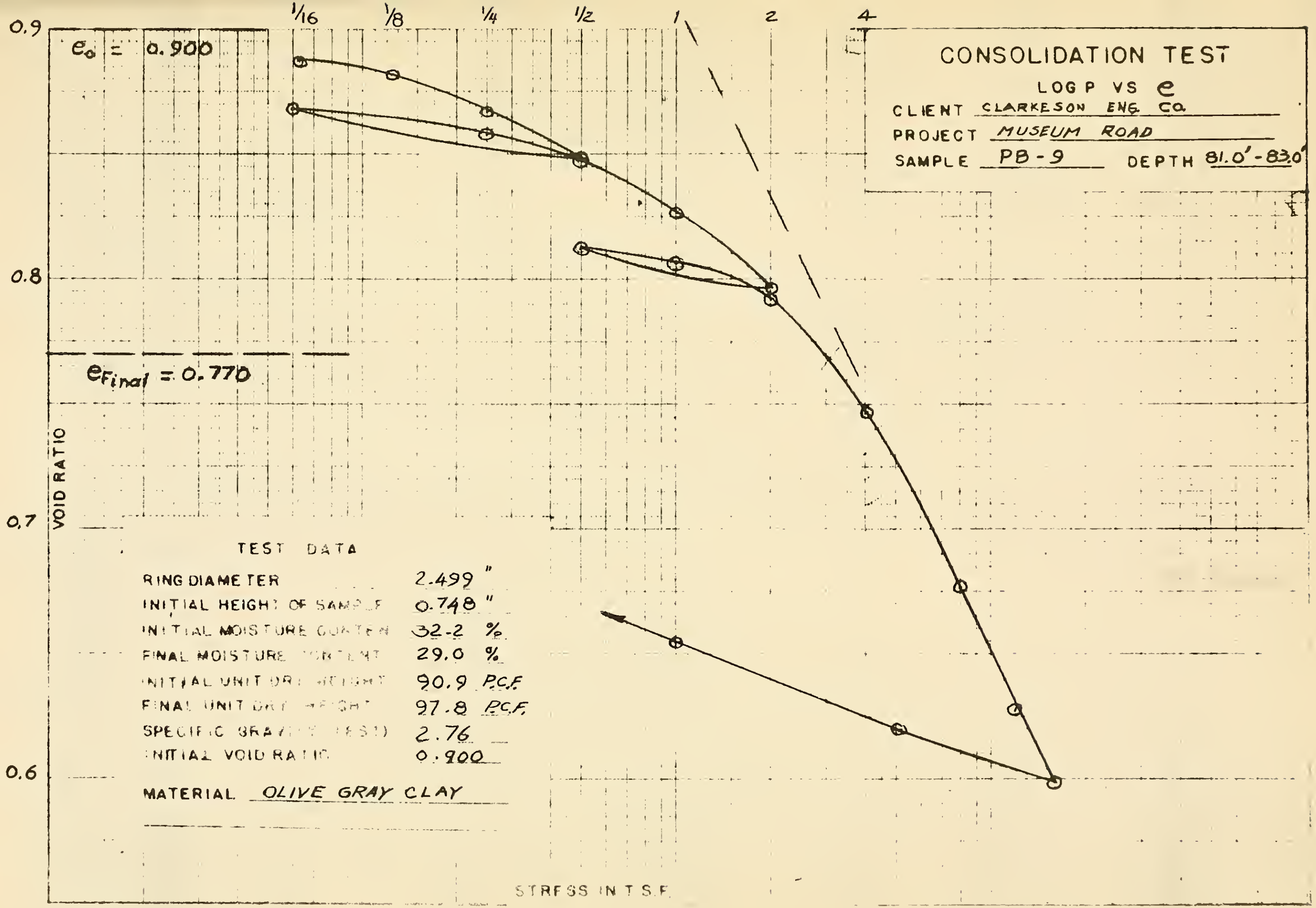


TEST DATA

RING DIAMETER	2.540"
INITIAL HEIGHT OF SAMPLE	0.749"
INITIAL MOISTURE CONTENT	26.7 %
FINAL MOISTURE CONTENT	23.9 %
INITIAL UNIT DRY WEIGHT	99.7 PCF
FINAL UNIT DRY WEIGHT	108.1 PCF
SPECIFIC GRAVITY	2.78
INITIAL VOID RATIO	0.738

MATERIAL OLIVE GRAY CLAY, TRACE OF FINE GRAVEL

THE HALLER TESTING LABORATORIES, INC.



CONSOLIDATION TEST

LOG P VS e

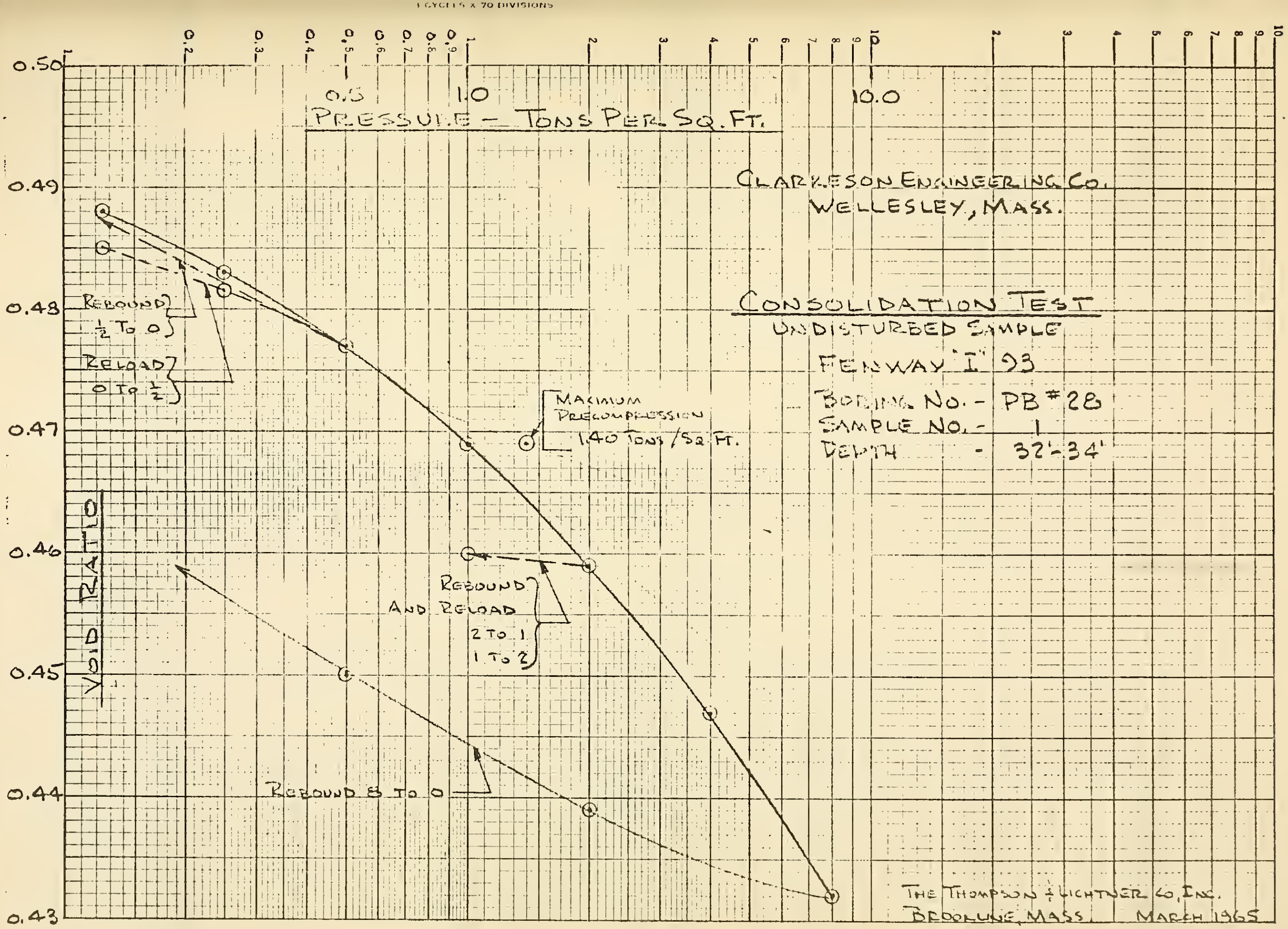
CLIENT CLARKESON ENG. CO.
PROJECT MUSEUM ROAD
SAMPLE PB-9 DEPTH 81.0'-83.0'

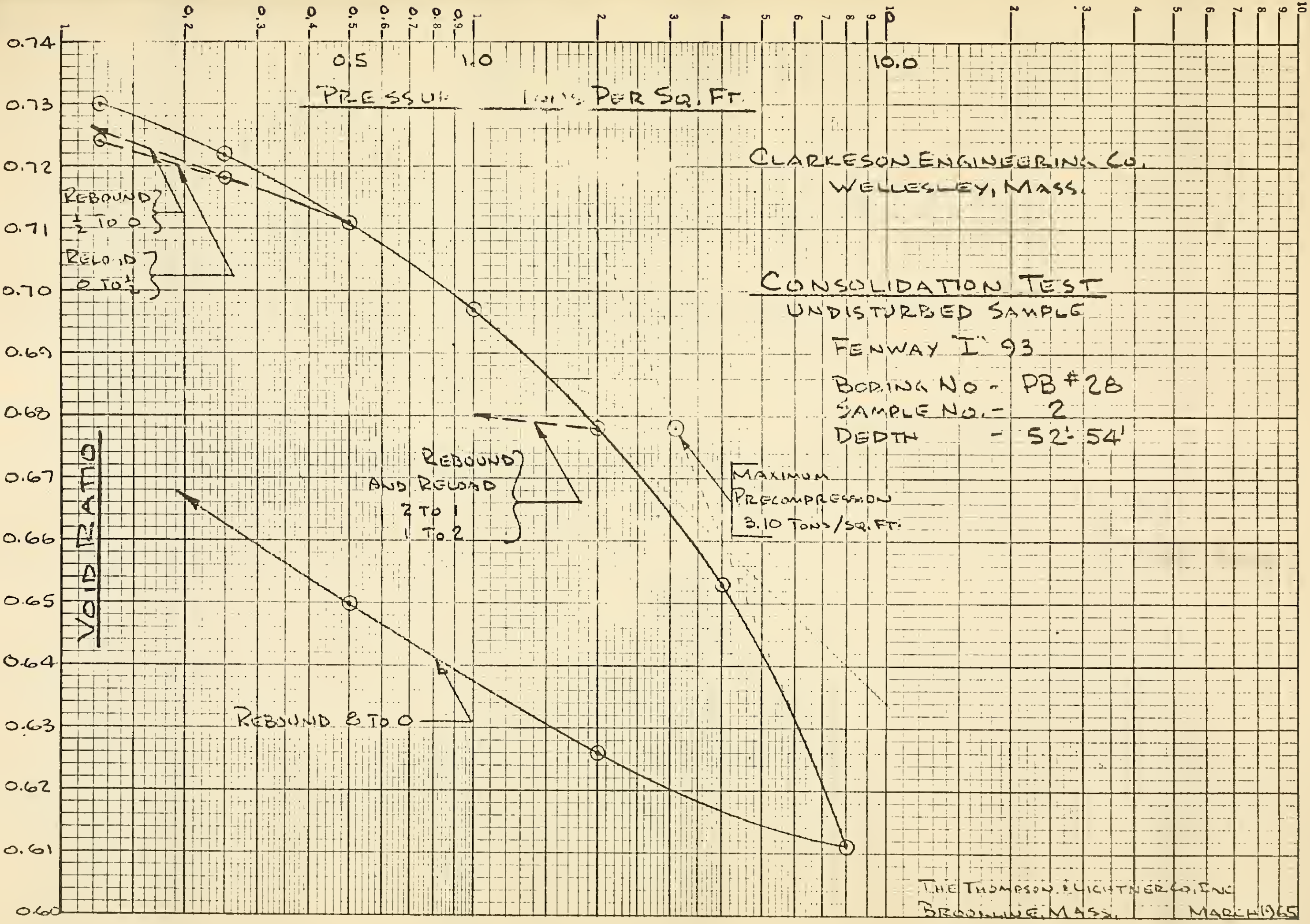
TEST DATA

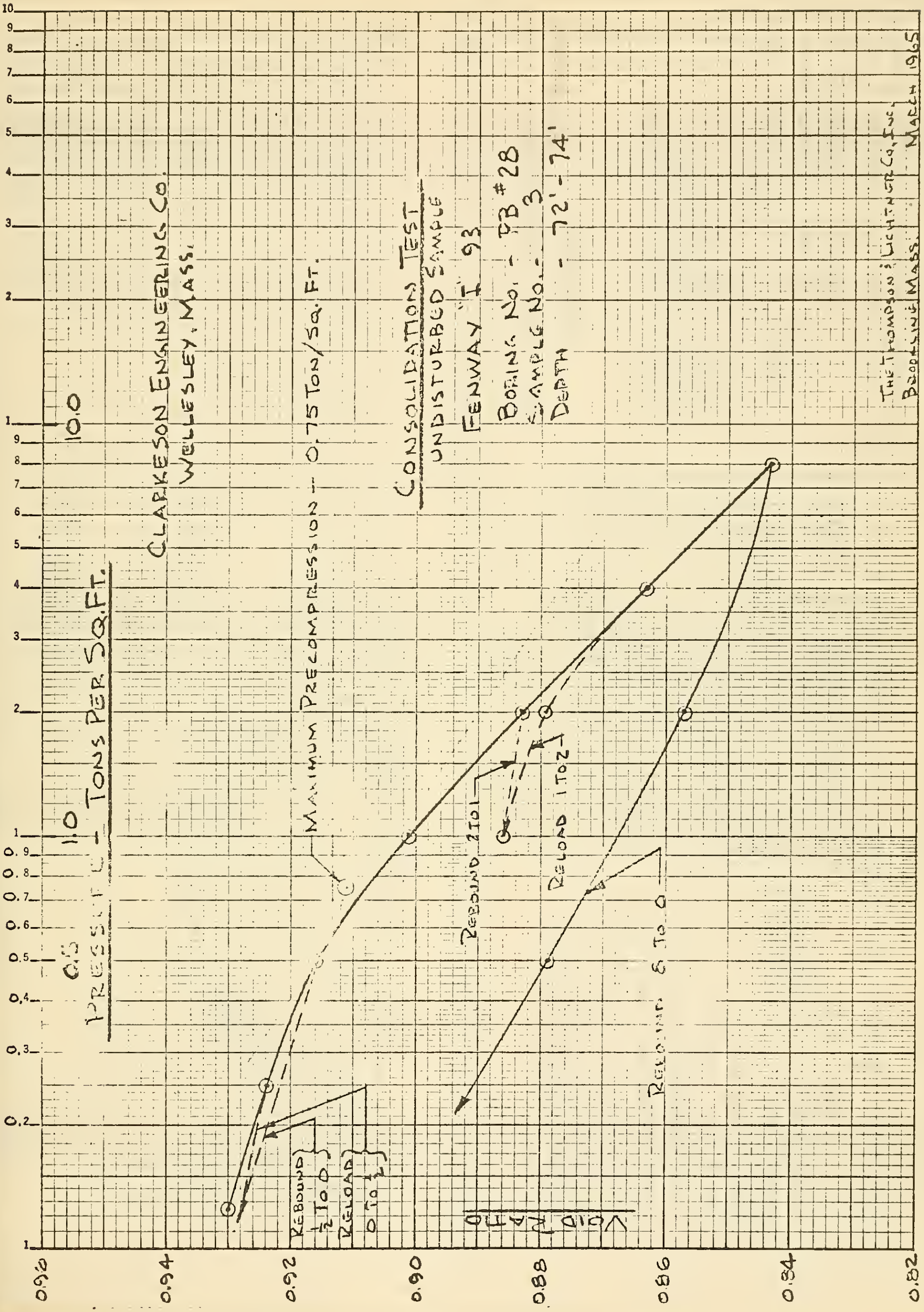
RING DIAMETER	2.499 "
INITIAL HEIGHT OF SAMPLE	0.748 "
INITIAL MOISTURE CONTENT	32.2 %
FINAL MOISTURE CONTENT	29.0 %
INITIAL UNIT DRY WEIGHT	90.9 P.C.F.
FINAL UNIT DRY WEIGHT	97.8 P.C.F.
SPECIFIC GRAVITY (TEST)	2.76
INITIAL VOID RATIO	0.900

MATERIAL OLIVE GRAY CLAY

THE HALLER TESTING LABORATORIES, INC

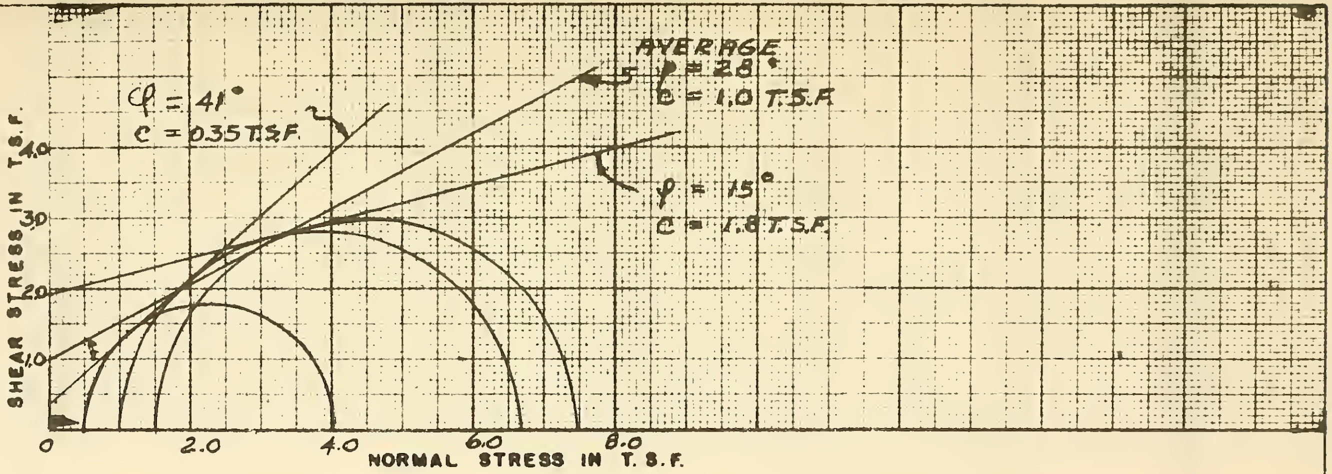

3 CYCLES x 70 DIVISIONS
CLARKESON ENGINEERING CO.
WELLESLEY, MASS.
CONSOLIDATION TEST
UNDISTURBED SAMPLE
FENWAY "I" 93
BORING NO. - PB # 28
SAMPLE NO. - 1
DEPTH - 32'-34'
PRESSURE - TONS PER SQ. FT.
0.5
1.0
10.0
VOID RATIO
0.50
0.49
0.48
0.47
0.46
0.45
0.44
0.43
MAXIMUM PRECOMPRESSION 1.40 TONS / SQ. FT.
REBOUND ½ TO 0
RELOAD 0 TO ½
REBOUND AND RELOAD 2 TO 1 1 TO 2
REBOUND 8 TO 0
THE THOMPSON & LICHTNER CO., INC.
BROOKLINE, MASS.
MARCH 1965


CLARKESON ENGINEERING CO.
WELLESLEY, MASS.
CONSOLIDATION TEST
UNDISTURBED SAMPLE
FENWAY "I" 93
BORING NO - PB #28
SAMPLE NO. - 2
DEPTH - 52'-54'
PRESSURE TONS PER SQ. FT.
VOID RATIO
0.5
1.0
10.0
0.74
0.73
0.72
0.71
0.70
0.69
0.68
0.67
0.66
0.65
0.64
0.63
0.62
0.61
0.60
REBOUND ½ TO 0
RELOAD 0 TO ½
REBOUND AND RELOAD 2 TO 1 1 TO 2
MAXIMUM PRECOMPRESSION 3.10 TONS/SQ. FT.
REBOUND 8 TO 0
THE THOMPSON & LICHTNER CO. INC
BROOKLINE, MASS.
MARCH 1965


Clarkeson Engineering Co.
Wellesley, Mass.
Consolidation Test
Undisturbed Sample
Fenway I 93
Boring No. - TB #28
Sample No. - 3
Depth - 72'-74'
The Thompson & Lichtner Co., Inc.
Brookline Mass. March 1965
Maximum Precompression - 0.75 Ton/Sq. Ft.
Pressure - Tons Per Sq. Ft.
0.5
1.0
10.0
Void Ratio
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
Rebound 2 to 1
Reload 1 to 2
Rebound 8 to 0
Rebound 1/2 to 0
Reload 0 to 1/2
1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
3
4
5
6
7
8
9
10

SHEET NO. 18

TRI-AXIAL SHEAR TEST MOHR CIRCLE ANALYSIS



TRI-AXIAL SHEAR TEST

TEST DATA

CLIENT CLARKESON ENG. CO.

PROJECT MUSEUM ROAD

SAMPLE PB-22X

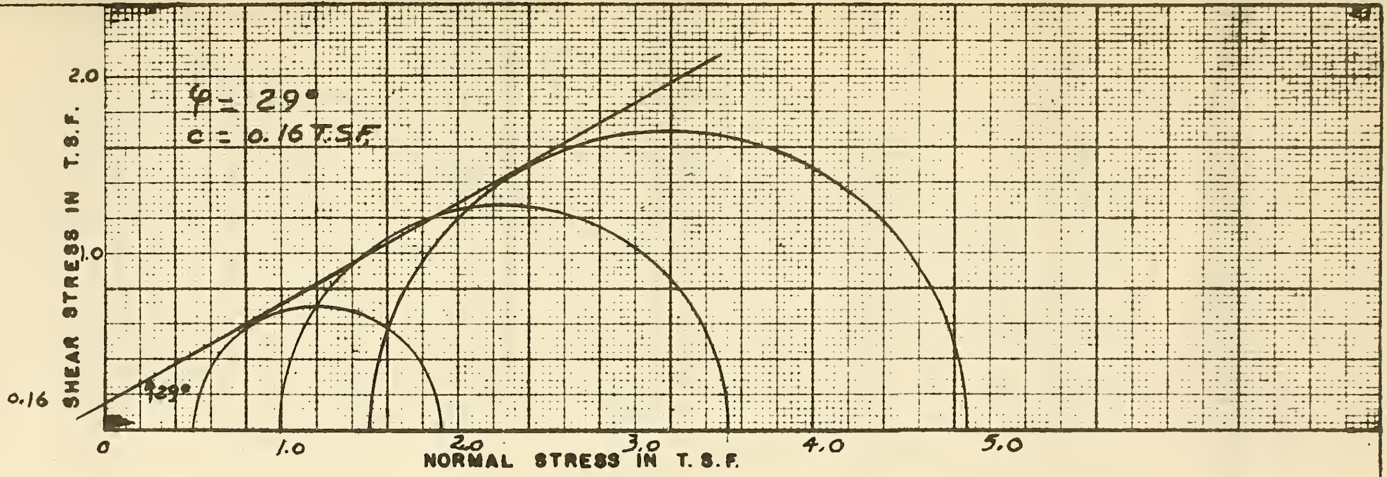
DEPTH 26.0' - 28.0'

MATERIAL OLIVE GRAY CLAY LITTLE MEDIUM FINE GRAVEL, (VARVED)

	TEST 1	TEST 2	TEST 3
LATERAL PRESSURE (T.S.F.)	0.5	1.0	1.5
INITIAL SAMPLE DIAMETER (IN.)	1.5	1.5	1.5
INITIAL HEIGHT OF SAMPLE (IN.)	3.125	3.0625	3.0625
INITIAL MOISTURE CONTENT (%)	29.8	26.3	24.7
FINAL MOISTURE CONTENT (%)	31.1	28.1	26.3
INITIAL UNIT DRY WEIGHT (P.C.F.)	96.2	100.5	96.1
INITIAL VOID RATIO	0.815	0.74	0.815
AMOUNT OF CONSOLIDATION { AXIAL (IN.)	0	0.012	0.036
AMOUNT OF CONSOLIDATION { VOLUME (C.C.)	0.7	0.3	0
(MAX. T.S.F.)	4.050	6.645	7.480

THE HALLER TESTING LABORATORIES, INC.

TRI-AXIAL SHEAR TEST MOHR CIRCLE ANALYSIS



	TEST 1	TEST 2	TEST 3
LATERAL PRESSURE (T.S.F.)	0.5	1.0	1.5
INITIAL SAMPLE DIAMETER (IN.)	1.5	1.5	1.5
INITIAL HEIGHT OF SAMPLE (IN.)	3.1875	3.125	3.125
INITIAL MOISTURE CONTENT (%)	28.1	27.9	27.2
FINAL MOISTURE CONTENT (%)	28.0	27.5	26.9
INITIAL UNIT DRY WEIGHT (P.C.F.)	94.6	101.0	101.0
INITIAL VOID RATIO	0.815	0.70	0.70
AMOUNT OF CONSOLIDATION { AXIAL (IN.)	0	0	0
AMOUNT OF CONSOLIDATION { VOLUME (C.C.)	0	0	0.10
(MAX. T.S.F.)	1.910	3.5275	4.885

TRI-AXIAL SHEAR TEST
TEST DATA

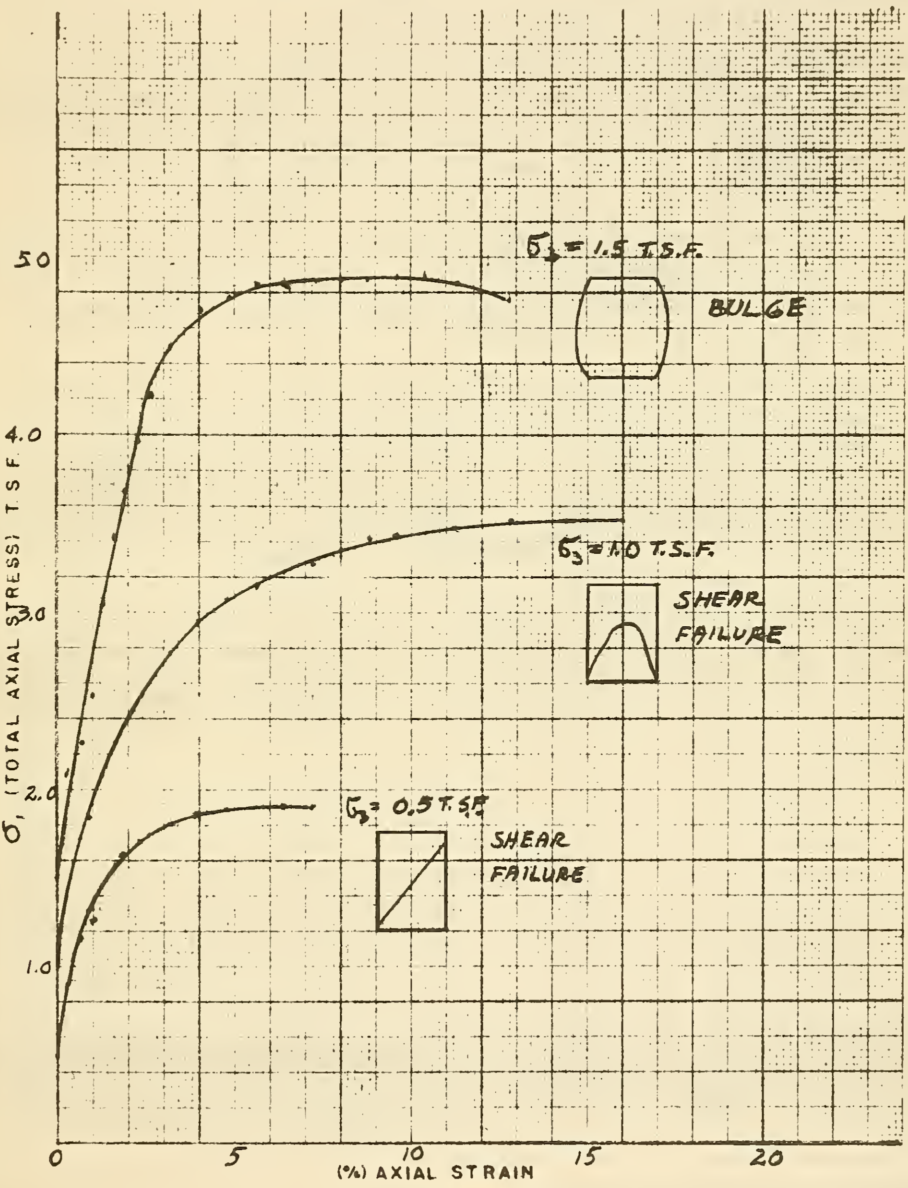
CLIENT CLARKESON ENG CO.
PROJECT MUSEUM ROAD
SAMPLE PB-22X
DEPTH 38.0'-40.0'
MATERIAL OLIVE GRAY SILT AND CLAY (VARIED) IN TEST #1
OLIVE GRAY CLAY IN TESTS #2 & #3

THE HALLER TESTING LABORATORIES, INC.

TRI-AXIAL SHEAR TEST

STRESS-STRAIN CURVES

CLIENT CLARKESON ENG. CO.
SAMPLE PB-22X
PROJECT MUSEUM ROAD
DEPTH 38.0'– 40.0'



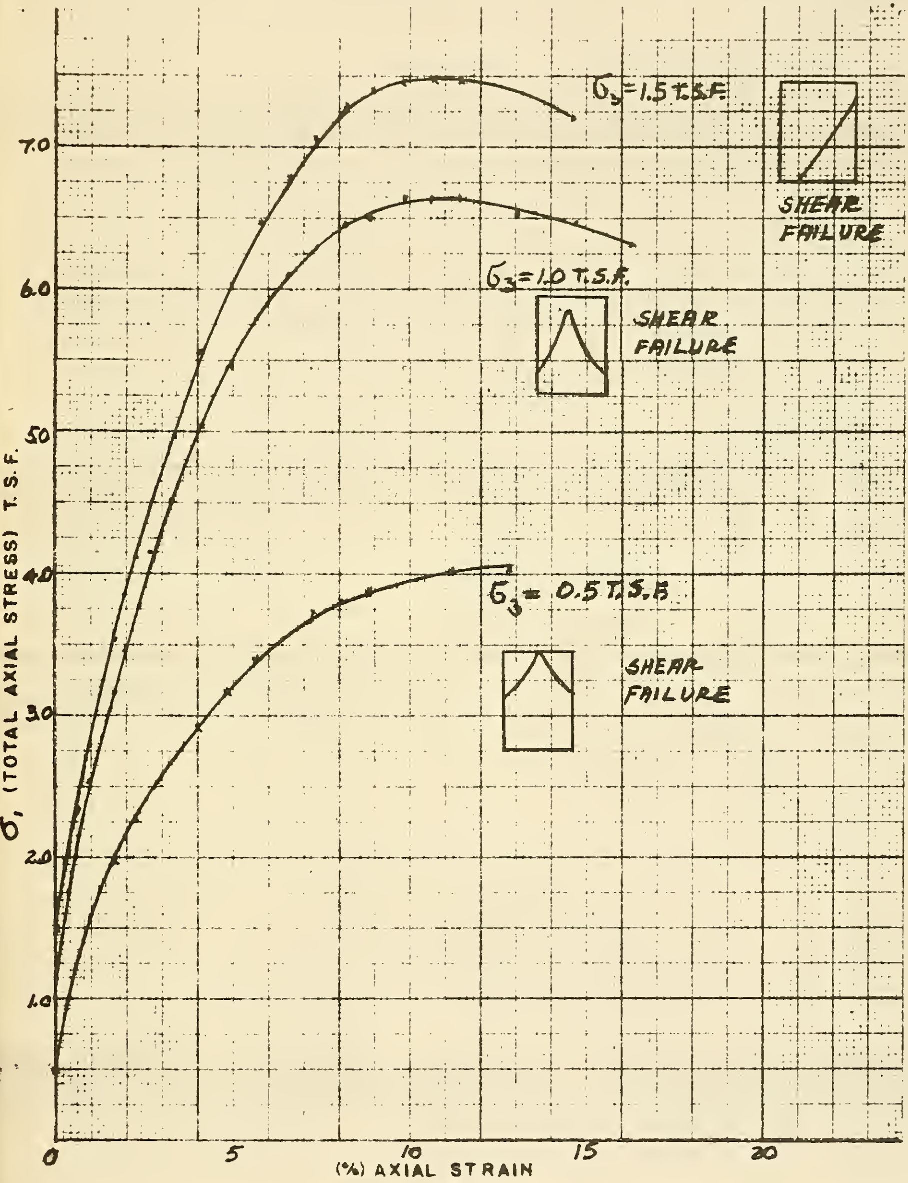
SHEET NO. 19

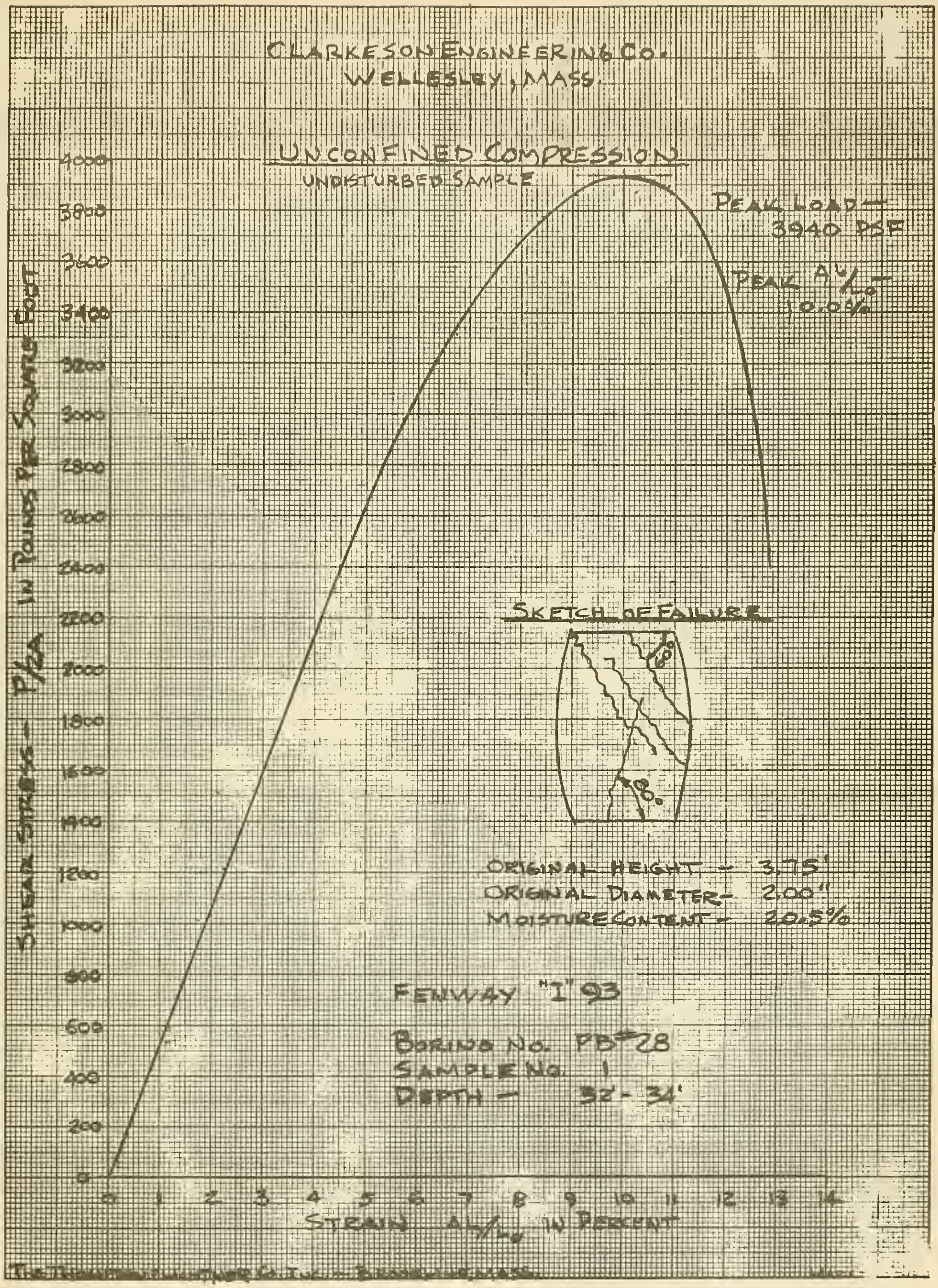
TRI-AXIAL SHEAR TEST

STRESS STRAIN CURVES

CLIENT CLARKESON ENG. CO. SAMPLE PB-22X

PROJECT MUSEUM ROAD DEPTH 26.0'-28.0'

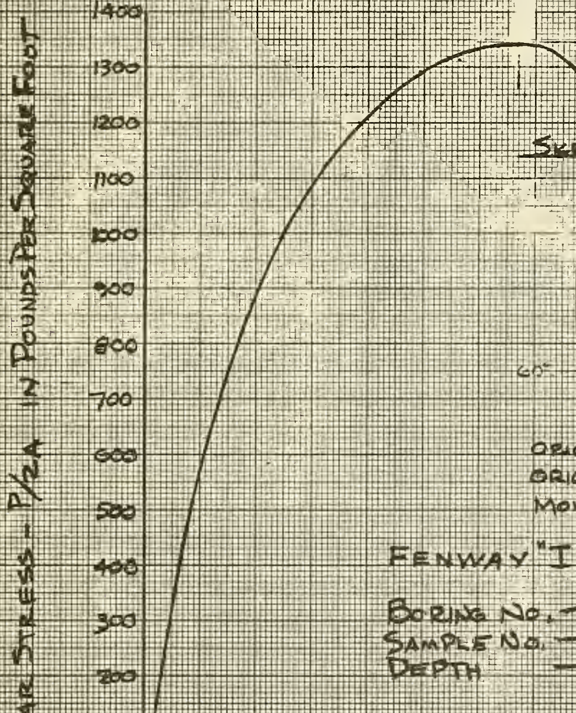



CLARKESON ENGINEERING CO.
WELLESLEY, MASS.
UNCONFINED COMPRESSION
UNDISTURBED SAMPLE
PEAK LOAD — 3940 PSF
PEAK ΔL/L₀ — 10.0%
SHEAR STRESS — P/2A IN POUNDS PER SQUARE FOOT
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
STRAIN ΔL/L₀ IN PERCENT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
SKETCH OF FAILURE
68°
8°
ORIGINAL HEIGHT — 3.75'
ORIGINAL DIAMETER — 2.00"
MOISTURE CONTENT — 20.5%
FENWAY "I" 93
BORING NO. PB#28
SAMPLE NO. 1
DEPTH — 32'-34'

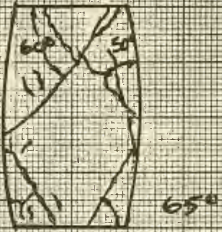
CLARKESON ENGINEERING CO.
WELLESLEY, MASS.

UNCONFINED COMPRESSION
UNDISTURBED SAMPLE

PEAK LOAD — 1345 PSF
PEAK ΔL/L₀ — 13.4%



SKETCH OF FAILURE



ORIGINAL HEIGHT — 7.000"
ORIGINAL DIAMETER — 2.812"
MOISTURE CONTENT — 30.2%

FENWAY "I" 93

BORING NO. — PB#28
SAMPLE NO. — 2
DEPTH — 52'-54'

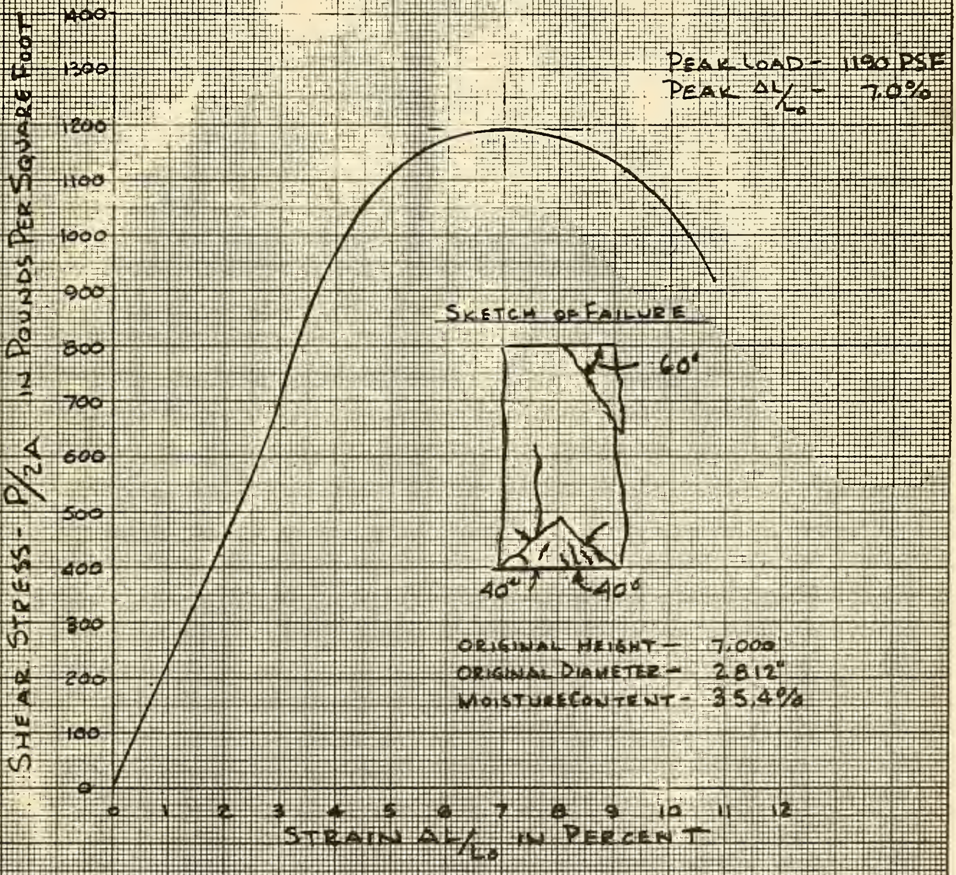
[illegible] Lightner Co., Inc., Brookline, Mass. [illegible]

CLARKESON ENGINEERING CO.
WELLESLEY, MASS.

UNCONFINED COMPRESSION
UNDISTURBED SAMPLE

FENWAY "T" 93

BORING NO - P8 #28
SAMPLE NO - 3
DEPTH - 72'-74'



PEAK LOAD - 1190 PSF
PEAK $\Delta L/L_0$ - 7.0%

ORIGINAL HEIGHT - 7.000"
ORIGINAL DIAMETER - 2.812"
MOISTURE CONTENT - 35.4%

APPENDIX B

HYDRAULIC STUDY OF THE PROPOSED RELOCATION OF MUDDY RIVER IN CLOSED CONDUITS

INTERSTATE ROUTE 695 CITY OF BOSTON

HYDRAULIC STUDY OF THE PROPOSED RELOCATION OF MUDDY RIVER IN CLOSED CONDUITS

TABLE OF CONTENTS

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Scope of Report	1
Summary of Conclusions and Recommendations	2
Hydrology-Criteria and Computations	7
Conduits - Design Computations	11
Cost Analysis	16
Exhibits	

LIST OF EXHIBITS

EXHIBIT NO.	
1	Drainage Area
2	Curves for Hydrologic Computations
3	Location Map of Proposed Conduit
4	Profile of Proposed Conduit
5	Cross Section of Proposed Conduit
6	Location Map of Alternate Conduit
7	Profile of Alternate Conduit
8	Cross Section of Alternate Conduit
9	Alternate Intake Structure & Inlet Well
9a	Alternate Intake Structure Details
10	Diversion Structure Details
11	Profile of New 9' X 11' Conduit
12	Outlet Structure Detail

SCOPE OF REPORT

As a result of the proposed depressed profile of Interstate Route 695 in the Fens area it is necessary to carry the floodflows of Muddy River in a system of closed conduits from the point where the River is intercepted to the Charles River Basin.

This Report summarizes the findings and recommendations of studies to determine the required size and the location of these conduits and an estimate of their cost.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

I. HYDROLOGY:

The drainage area tributary to Muddy River is 2,380 acres.

The 50 year flood discharge from the Muddy River drainage area, taking into account available storage, was computed to be 1,180 CFS.

II. HYDRAULIC GRADIENT OF PROPOSED SYSTEM:

The normal water level in the Charles River Basin is el. 2.5'. Extreme high water during the 1955 hurrican was el. + 7.02'.

The total head loss due to the 50 year flood discharge flowing through the proposed system will be 7.5'.

This will cause the following high water elevations in Muddy River, upstream of the proposed intake structure:

> 50 year flood on watershed coinciding with normal water level in Charles River --- el. 10'.
>
> 50 year flood on watershed coinciding with high water in Charles River --- el. 12.5'.
>
> 50 year flood on watershed coinciding with extreme high water in Charles River --- el. 14.5'.

Since these high water levels together with the elimination of part of the Muddy River will obstruct the flow of storm water from the Fenway, an additional storm sewer system with an inverted syphon under Interstate Route 695, connecting directly to the Fens Pond is proposed. This separate storm drain system will drain a 70 acre area.

It should be noted that the coincidence of a 50 year flood discharge with extreme high water in Charles River has a frequency of recurrence far in excess of 50 years.

III. PROPOSED STRUCTURE:

1. Intake Structure: (See Exhibit 9)

One 4' X 6' sluice gate is provided for the regular flow, and two additional 9' X 9' sluice gates will open only during major floods. A trash rack is provided ahead of the sluice gates.

The gates will be motor operated and their operation regulated by the upstream water level. An alarm system will be provided in case of malfunction of the automatic control.

The intake structure will be accommodated in a 600 square foot, architecturally designed gatehouse.

2. Conduit from the Intake Structure to the Syphon Well on Brookline Avenue:

A box conduit is proposed from the Intake Structure to the syphon well, consisting of two 90 S.F. conduits and one 24 S.F. conduit. (See Exhibit 5).

The 28' wide by 14' high conduit will have a net wet cross section of 204 S.F. which will be subdivided into three separate conduits: one 24 S.F. conduit to accommodate the dry weather flow and minor floods; two 90 S.F. conduits to operate only during major floods. This arrangement will make it possible to maintain self-cleaning velocities in the conduits thereby reducing maintenance cost.

3. Inverted Syphon at Brookline Avenue:

An inverted syphon is proposed under the depressed roadway, consisting of: an intake well; a 280' box conduit monolithic with the depressed road; and an outlet well to the diversion chamber, (See Exhibits 9, 10 & 11).

An alternate scheme using a 20' O.D. tunnel was also studied and is illustrated, (See Exhibits 6, 7 & 8).

4. Diversion Chamber on Brookline Avenue:

The function of this structure is to distribute the flow of the Muddy River between the existing 9' X 11' conduit paralleling Brookline Avenue which outlets to the Charles River and the proposed new 9' X 11' conduit which outlets to the Fens Pond.

Two motor operated 9' X 11' sluice gates will permit the diversion of the entire flow to either the existing or the new 9' X 11' conduits for maintenance purposes. These gates will open automatically under flood conditions. The conduits leading to the diversion chamber from the outlet well of the syphon will have flap valves at their outlet which

will make it possible to isolate a single conduit for dewatering and maintenance.

The diversion structure will be accommodated in an architecturally designed gatehouse.

4. Conduit from the Diversion Structure to the Fens Pond:

A 9' X 11' conduit, 1,950' long, is proposed alongside Interstate 695 with an outlet to the Fens Pond.

5. Outlet Structure at Fens Pond:

The outlet structure will consist of a stonefaced headwall and a flap valve to facilitate maintenance.

6. Additional Storm Sewer Along the Fenway:

This storm sewer will drain a 70 acre area during high water conditions upstream of the Muddy River inlet.

The purpose of this sewer will be to collect all sewer and surface drain inlets and the overland flow along the Fenway and convey this flow to the proposed inverted syphon.

7. Inverted Syphon for Additional Storm Sewer:

The syphon consists of two 48" dia. conduits and one 24" dia. conduit. Flow to these conduits will be regulated by weirs of different crest elevations, so that only the 24" dia. conduit will operate

during minor floods.

ADVANTAGES OF THE PROPOSED AND ALTERNATE SCHEMES:

The proposed scheme has the following advantages: it could be constructed without disturbing the existing outlet system to Brookline Avenue; its inverted syphon could be built to be monolithic with the proposed Inner Belt road foundation; and, assuming no interference with either the Beth Israel Dormitory or the existing 11' O.D.M.D.C. sewer, it has a construction cost that is approximately 16% less than that of the alternate scheme.

The Alternate scheme has the following advantages: it could be constructed without disturbing the existing outlet system to Brookline Avenue or to the Fens Pond; its inverted syphon could be tunneled and be independent from the proposed Inner Belt road; it would have a smaller head loss than the proposed scheme; and, if a more detailed survey indicates interference with either the Beth Israel Dormitory or the existing 11" O.D. M.D.C. sewer, it might have a cost advantage over the proposed scheme.

Both schemes would have an advantage over the existing system, in that they would provide adequately for the present and future needs of the system.

The two recently installed 72" dia. conduits between the intake structure and the gatehouse, (see Exhibits 3 & 6), are inadequate. The Brookline Town Engineer has stated that flooding has occurred in the area since their construction.

HYDROLOGIC STUDY OF MUDDY RIVER

REFERENCES:

I. U. S. Weather Bureau, Technical Paper No. 25

II. Flood Flows, By W. E. Fuller. A.S.C.E. Transactions, 70 - 564

III. Flood Formulas, By Kinnison and Colby. A.S.C.E. Paper #2448

IV. Sewer Districts, Town of Brookline

V. Horton, Proc. Soil Science Society of America 3, pages 340 - 349

ASSUMPTION:

The drainage areas dealt with in this study are fully or partially developed urban areas.

Although at the present time some undeveloped areas and inadequacies in the existing sewerage system will tend to decrease floodflows, (for the purpose of this study) all drainage areas were treated as fully developed urban areas with adequate storm drainage. Any existing undeveloped areas and inadequacies in the sewerage system are considered to be of a temporary nature.

The drainage area tributary to Muddy River above the proposed intake structure was determined to be 2,380 acres, (See Exhibit 1).

The drainage areas of Jamaica Pond and Brookline Reservoir were excluded from the tributary area, since overflow from these areas to Muddy River is not significant.

The storage area provided by the Muddy River is 24 acres, having a storage capacity of 144 acre-feet at maximum flood elevation. The assumption of a 6' depth of storage is based on the hydraulic gradient through the proposed system due to the 50 year storm.

Runoff computations are based on the rational formula using a coefficient of runoff of 0.55, and rainfall intensities based on Ref. I (See Exhibit 2).

The effect of storage was accounted for by relationships developed by Fuller (Ref. II) see Exhibit 2.

This approach is based on the assumption that Fuller's relationship, using a parabolic hydrograph will approximate the results that would be obtained by floodrouting. The actual floodflows would be more closely represented by a hydrograph as developed by Horton (Ref. IV). The use of the parobolic hydrograph will tend to decrease the reduction of runoff due to storage and is therefore on the safe side.

Results obtained in the above manner are compared to floodflows by the Kinnison-Colby formula (Ref. III), increased by 50% to account for the urban area. Results obtained by the Kinnison-Colby formula are of the same order of magnitude.

COMP. BY F. Y.
CHECK BY J. A. B.
ACTIV. NO.
DATE
LOCATION

SUBJECT RUNOFF COMPUTATIONS

MUDDY RIVER

C = 0.55
Vi = TOTAL VOLUME FLOWING INTO STORAGE
Vs = VOLUME STORAGE
i = RAINFALL INTENSITY (EXHIBIT 2)
K = COEFFICIENT OF STORAGE (EXHIBIT 2)
A = DRAINAGE AREA
Q = K (CiA)

50 YEAR FLOOD

A = 2,380 ACRES AT 2 HOUR RAINFALL
i_{50} = 1.3 IN. / HOUR
Vi = 0.55 × 1.3 × 2,380 × $\frac{1}{12}$ × 2 = 284 AC-FT.
Vs = 6 × 24 = 144 AC.-FT.

$\frac{V_s}{V_i} = \frac{144}{284} = 0.505$

K = 0.69 (EXHIBIT 2)
Q_{50} = 0.69 × 0.55 × 1.3 × 2,380 = 1,180 CFS
Vi i A

25 YEAR FLOOD

AT 2½ HOUR RAINFALL i = 1 IN./HR.
Vi = 0.55 × 1 × 2,380 × $\frac{1}{12}$ × 2.5 = 273 AC-FT.

$\frac{V_s}{V_i} = 0.53$ K = 0.65

Q_{25} = 0.65 × 0.55 × 2,380 = 850 C.FS

COMP. BY F.Y

CHECK BY J.A.B.

ACTIV. NO.

CLARKESON ENGINEERING CO., INC.

ENGINEERS

SHEET 10 OF

DATE

LOCATION

SUBJECT ALTERNATE METHOD

KINNISON - COLPY FORMULA

1.5 x THE KINNISON - COLBY DISCHARGE
IS USED TO ACCOUNT FOR THE URBAN AREA

$$a = \frac{24}{2{,}330} \times 100 = 1.01\,\%$$

S = 120 - 3 = 117'

M = 3.72 SQ MILES

L = 2 MILES

RARE FLOOD

$$Q = 1.5\,(0.0595 \times S^{1.5} + 342) \times \frac{M^{0.95}}{L^{0.7}}$$

$$= (0.0595 \times 1268 + 342)\ \frac{3.48}{1.62} = 1{,}340 \text{ CFS}$$

$$Q_{\text{RARE}} = 1{,}340 \text{ CFS}$$

MAJOR FLOOD

$$Q = 1.5\,(0.0344 \times S^{1.5} + 200) \times \frac{M^{0.85}}{L^{0.5}} = 780 \text{ CFS}$$

MINOR FLOOD

$$Q = 1.5\,(0.000036 \times S^{2.4} + 124) \times \frac{M^{0.95}}{a^{0.04} \times L^{0.7}} = 410 \text{ CFS}$$

COMP. BY E. Y.
CHECK BY J.A.B.
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 11 OF
DATE
LOCATION

SUBJECT MUDDY RIVER

HYDRAULIC COMPUTATIONS

INLET TO BROOKLINE AVE DIVERSION CHAMBER

PROPOSED SCHEME

1 BOX CONDUIT $R = 1.2'$ $A = 24\ \square'$
2 BOX CONDUIT $R = 2.17'$ $A = 91.25\ \square'$

TOTAL LENGTH OF CONDUITS

SHALLOW CONDUIT = 695'
INVERTED SYPHON = 280'
2 VERTICAL SHAFTS = 80'
TOTAL LENGTH 1055'

HEAD LOSS COEFFICIENTS
INLET $1.2 \frac{V^2}{2g}$
5-90° BENTS $2.0 \frac{V^2}{2g}$ $(.4 \frac{V^2}{2g}$ EACH$)$
TOTAL LOSS $3.2 \frac{V^2}{2g}$

LOSS ACROSS TRASHRACK SAY 0.5'

SAY V_1 = VELOCITY IN LARGE TUBES
V_2 = VELOCITY IN SMALL TUBES

$$H_{f_1} + 3.2 \frac{V_1^2}{2g} = H_{f_2} + 3.2 \frac{V_2^2}{2g}$$

$n = 0.013$

COMP. BY F. Y.
CHECK BY J. A. B
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 12 OF
DATE
LOCATION

SUBJECT

531 CFS IN EACH LARGE TUBE
118 CFS IN THE SMALL TUBE

$$\begin{array}{r} 1062 \text{ CFS} \\ \underline{118} \\ \Sigma \varphi = 1{,}180 \text{ CFS} \end{array}$$

$V_1 = 5.83$ FPS

$H_{f_1} = .00085 \times 1055 = 0.91'$

$H_{e_1} = 3.2 \times \frac{5.83^2}{64.4} = \underline{1.69}$

$2.60'$

$V_2 = 4.91$ FPS

$H_{f_2} = .00134 \times 1055 = 1.41'$

$H_{e_2} = 3.2 \times \frac{4.91^2}{64.4} = \underline{1.21'}$

2.62

$\underline{\underline{\Sigma H}} = 2.6 + 0.5 = 3.1'$

ALTERNATE SCHEME (Φ 20' TUNNEL)

2 TUBES : R = 2.5'   A = 90 □'
1 TUBE : R = 1.14'   A = 24 □'

TOTAL LENGTH INCL. VERT. SHAFTS : 850'
HEAD LOSS COEFFICIENTS

INLET : $1.2 \frac{V^2}{2g}$
4 - 90° BENTS : $\underline{1.6 \frac{V^2}{2g}}$

TOTAL LOSS $2.8 \frac{V^2}{2g}$

LOSS ACROSS TRASHRACK SAY 0.5'
V_1 = VELOCITY IN LARGE TUBES
V_2 = VELOCITY IN SMALL TUBES

$$H_{f_1} + 2.8 \frac{V_1^2}{2g} = H_{f_2} + 2.8 \frac{V_2^2}{2g}$$

$n = 0.013$

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542 CFS IN EACH LARGE TUBE 1084 CFS
116 CFS IN THE SMALL TUBE 116

$\Sigma \varphi = 1,200$ CFS

$V_1 = 6.01$ FPS
$H_{f1} = .0008 \times 850 = 0.68$
$H_{e1} = 2.8 \times \frac{6.01^2}{64.4} = \underline{1.58}$
$2.26'$

$V_2 = 4.95$ FPS
$H_{f2} = .0015 \times 85 = 1.27'$
$H_{e2} = 2.8 \times \frac{4.95}{64.4} = \underline{1.01}$
$2.29'$

$\Sigma H = 2.26 + 0.50 = \underline{2.76'}$

HEAD LOSS BETWEEN DIVERSION CHAMBER AND CHARLES RIVER BASIN

ASUMPTION

UNDER 50 YEAR STORM DISCHARGE THE ELEVATION OF FENS POND WILL BE 0.5' ABOVE CHARLES RIVER BASIN. THIS IS BASED ON THE ASUMPTION THAT APPROX. 3,000 C.F.S WILL DISCHARGE INTO FENS POND

800 CFS FROM MUDDY RIVER
2,200 CFS FROM STONY BROOK

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OLD BROOKLINE AVE CONDUIT
3,030' – OLD ELLIPTICAL
$R = 2.48'$, $A = 77.7 \square'$ $n = 0.017$
410' – NEW 9.67' x 10' CONDUIT
$R = 2.45$, $A = 96.67 \square'$ $n = 0.013$
60' INVERTED SYPHON (ASUME L = 90')
1 TUBE 6.5' x 6.5' $R = 1.62'$ $A = 42.2 \square'$
1 TUBE 3.33' x 4' $R = 0.91'$ $A = 13.4 \square'$
$n = 0.013$

AT 380 CFS

INV. SYPHON

$Q = 292$ CFS
$V_1 = 6.90$ FPS

$1.6 \times \frac{V_1^2}{2g} = 1.18'$

$Hf_1 = .0017 \times 90 = 0.15'$
$1.33'$

$Q = 88$ CFS
$V_2 = 6.60$ FPS

$1.6 \frac{V_2^2}{2g} = 1.08'$

$Hf_2 = .0032 \times 90 = 0.29'$
$1.37'$

SAY $\Sigma \Delta H$ SYPHON = 1.35'

ELLIPTIC PIPE $V = \frac{380}{77.7} = 4.88'$

$Hf = .00085 \times 3{,}030 = 2.57'$
ΔH ENTRANCE $= 0.2 \times \frac{4.88^2}{64.4} = 0.07'$

ΔH EXIT (TO CHARLES RIVER) $= 0.75 \times \frac{4.88^2}{64.4} = 0.28'$

$\Sigma \Delta H = 2.92'$

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NEW 9.67'x 10' PIPE $V = \frac{380}{46.67} = 3.93'$

$n = .013$ $H_f = .00032 \times 410 = 0.13'$

TOTAL HEAD LOSS IN BROOKLINE AVE. CONDUIT

$\Sigma H = 1.37 + 2.92 + 0.13 = 4.42'$

NEW 9'x 11' CONDUIT

DIVERSION STRUCTURE TO FENS
LENGTH = 1,950'
$A = 99\square'$, $R = 2.47'$ $n = 0.013$

$Q = 1,180 - 380 = 800$ CFS

$V = 8.1$ FPS
$H_f = 0.0015 \times 1950 = 2.93'$
ENTR. LOSS $0.2 \frac{V^2}{2g} = 0.20$
EXIT. LOSS (AT FENS POND)
$= 0.75 \frac{V^2}{2g} = 0.76$

$\Sigma H = 3.89$

$4.42 - 3.89 = .53'$ – OK

0.53' DIFFERENCE BETWEEN CHARLES RIVER AND FENS POND

TOTAL HEAD LOSS

INLET TO CHARLES RIVER PROPOSED SCHEME

$\Sigma H = 4.42' + 2.76 = \underline{7.18'}$

COST ANALYSIS

PROPOSED SCHEME (See Exhibits)

The proposed scheme consists of: an intake structure with trash racks and motor operated sluice gates enclosed in an architecturally treated building; a high level conduit paralleling the Fenway from the intake to the syphon at Brookline Avenue; an inverted syphon under the depressed road to the diversion chamber; a diversion chamber; a new 9' X 11' conduit to the Fens outlet; a tie into the existing 9' X 11' conduit on Brookline Avenue; and an outlet structure to the Fens Pond.

ALTERNATE SCHEME (See Exhibits)

The alternate scheme consists of a combination inlet structure and syphon shaft; a 20' dia. tunnel under the depressed road; a diversion structure; a new 9' X 11' conduit to the Fens Pond; a tie into the existing 9' X 11' conduit on Brookline Avenue; and an outlet structure to the Fens Pond.

Estimated Cost Of Proposed System

Intake Structure	80,000
High Level Conduit	405,000
Syphon	380,000
Diversion Structure	174,200
New 9'x11' Conduit	676,000
Tie To Existing 9'x11' Conduit	1,000
Outlet Structure	10,000
Storm Sewer Along Fenway (Approx.)	52,000
Syphon For Storm Sewer To Fens Pond	55,000
Total Cost Of Proposed System	$1,833,200

Estimated Cost Of Alternate System

Intake Structure	181,600
Tunnel	1,030,000
Diversion Structure	174,200
New 9'x11' Conduit	676,000
Tie To Old 9'x11' Conduit	4,000
Outlet Structure	10,000
Storm Sewer Along Fenway (Approx.)	52,000
Syphon For Storm Sewer To Fens Pond	55,000
Total Cost Of Alternate System	$2,182,800

The Difference In Cost Between The Two Schemes Is Approx. $350,000.
If More Detailed Investigation Of The Proposed Scheme Should Indicate Encroachment On The Beth Isral Dormitory Building Or The 11'o.D. M.D.C. Sewer The Alternate Scheme Would Be More Economical.

Estimated Cost Of Proposed System

Intake Structure	80,000
High Level Conduit	405,000
Syphon	380,000
Diversion Structure	174,200
New 9'x11' Conduit	676,000
Tie To Existing 9'x11' Conduit	1,000
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Intake Structure	181,600
Tunnel	1,030,000
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Total Cost Of Alternate System	$2,182,800

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If More Detailed Investigation Of The Proposed Scheme Should Indicate Encroachment On The Beth Isral Dormitory Building Or The 11'o.d. M.D.C. Sewer The Alternate Scheme Would Be More Economical.

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SUBJECT COST ESTIMATE

PROPOSED INTAKE CONDUIT

600 LF HIGH LEVEL CONDUIT

Excavation	22 y^3 × \$2.5	=	\$ 55.00
Sheeting	50 SF @ \$4.0	=	200 00
Concrete			390.00
			\$645.00
Dewatering			27
			\$672.00

600 LF @ \$672 = \$405,000

300LF SYPHON UNDER (I 695)

Excavation	51 y^3 × 2.50	=	127.00
Sheeting	100 SF × 7.00	=	700.00
Concrete			390.00
Dewatering (1 month)			27.00
			\$1244.00

300 LF @ \$1244	=	\$374,000
		6,000
		\$380,000

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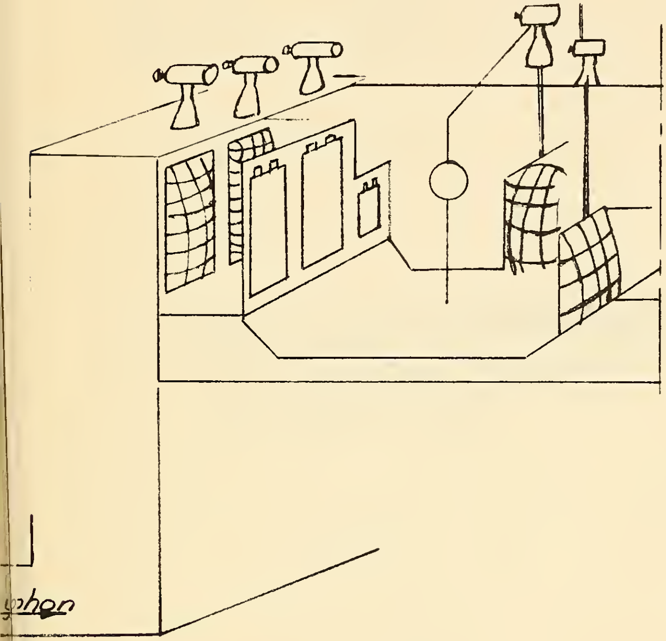
SUBJECT *Muddy River Diversion Chamber*



Excavation 340 yds + 25% = 430 yds @ 4.00	1,700
Sheathing 1100 sq. Ft. @ 3.00	3,300
Forms and Concrete 200 yds @ 80	16,200
	21,200 s
L/T and Controls/Sluice Gates	25,000
Flap Valves	14,000
Exit Gates/L/T Controls	20,000
	72,200
Well	102,000
	$ 174,200

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SUBJECT COST ESTIMATE

NEW 9'x11' CONDUIT (1,950 FT)

Concrete	70/27 x $80	$ 210.00
Excavation	170/27 x $2.5	16
Sheeting	48 SF x $2.5	120.00
		346.00/L.F.

1,950' x $346 =	$ 675,000
3 M.H.'s	1,000
	$ 676,000

TIE IN TO EXISTING 9'x11' CONDUIT

TIE IN TO 9'x11' CONDUIT	3500
JUNCTION BOX	500
	$ 4,000

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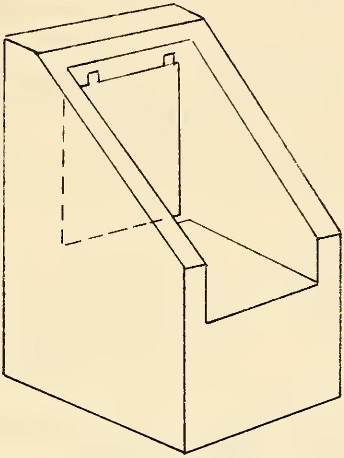
SUBJECT Fine Arts Outlet - Flap Outlet - Muddy River



Concrete	20 yds @ 20	400.00
Forms	300 Sq. Ft. @ 1.50	450.00
Flap Valves 8'x10'		6,000.00
Arch. Treatment		1,200.00
Excavation and Dredging		1,000.00
		$ 9,050.00

say $10,000

10688

SUBJECT Muddy River Intake Structure

ALTERNATE SCHEME

Intake	22,600
Inlet Well	102,000
Trash Rack	4,000
2-9x10 Sluice Gates and Controls	20,000
4x6 Sluice Gates and Controls	5,000
Piping	4,000
Electric Service	2,000
2 Dewatering Pumps	14,000
Misc. Iron	2,000
Arch. Treatment	6,000
	$181,600

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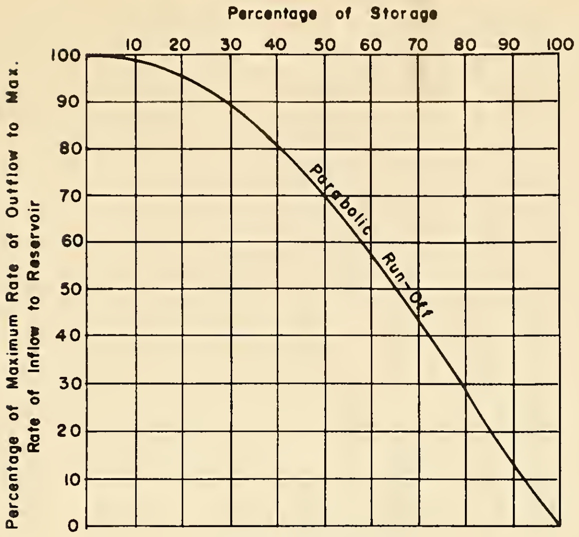
SUBJECT Alternate Scheme Cost Est. 20' Tunnel

11.65 Y³ @ $50		=	$ 585/LF
Shield	$25,000/750	=	34/LF
Concrete	4.85 y³ @ $80	=	390/LF
Lining	10 WF 35 @ 3' o.c = 700# @ $0.35	=	245/LF
Wood	Sheeting (3")		120/LF
			1,374/LF

750 L.F. x $1,374/L.F. = $ 1,030,000

EXHIBIT #2

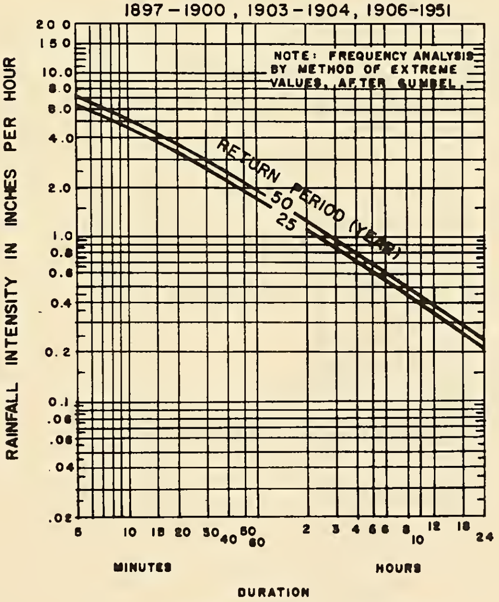
EFFECT OF STORAGE ABOVE THE OVER-FLOW UPON MAX. RATE OF FLOW



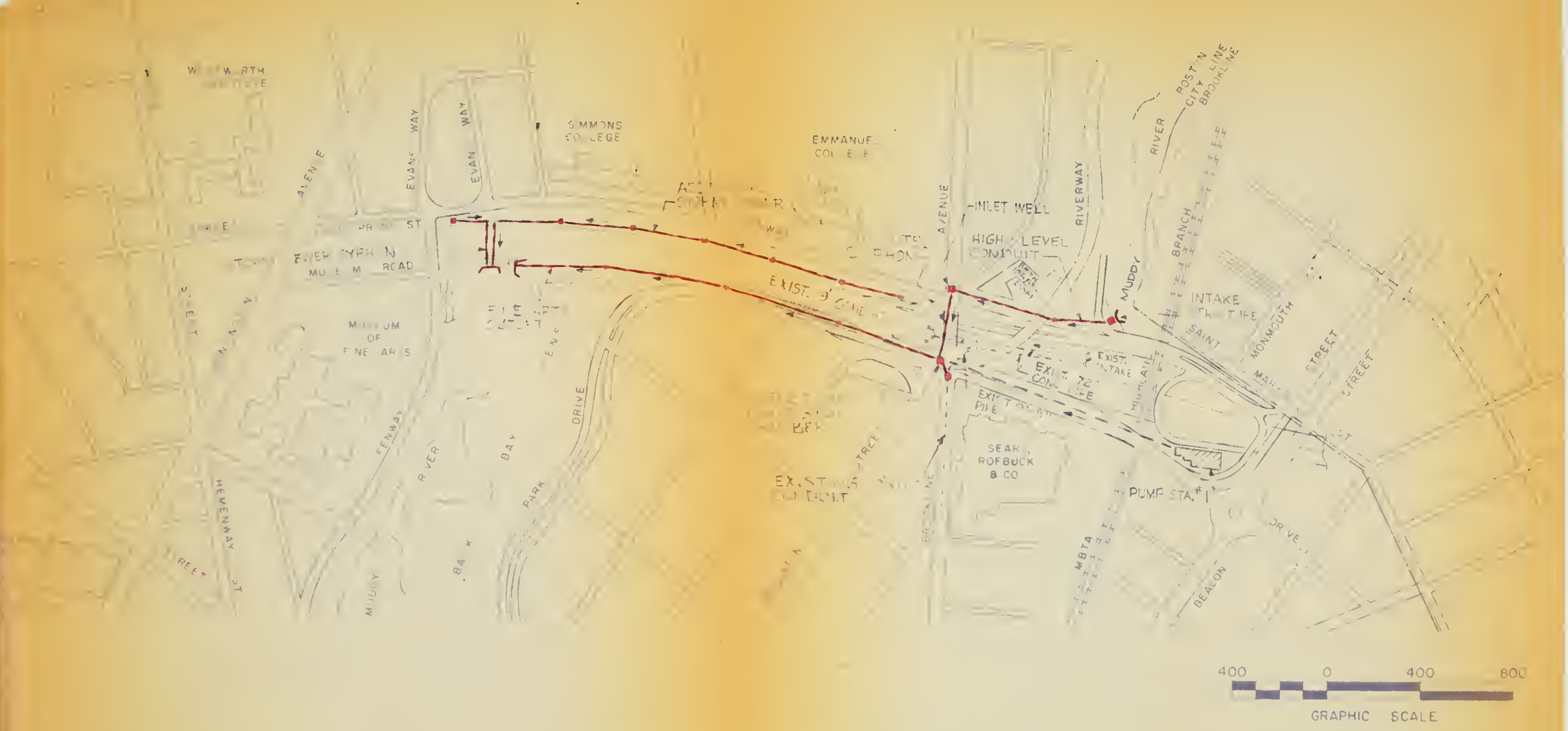
BY W. E. FULLER
A.S.C.E. TRANSACTIONS 70-564

RAINFALL INTENSITY – DURATION – FREQUENCY CURVES

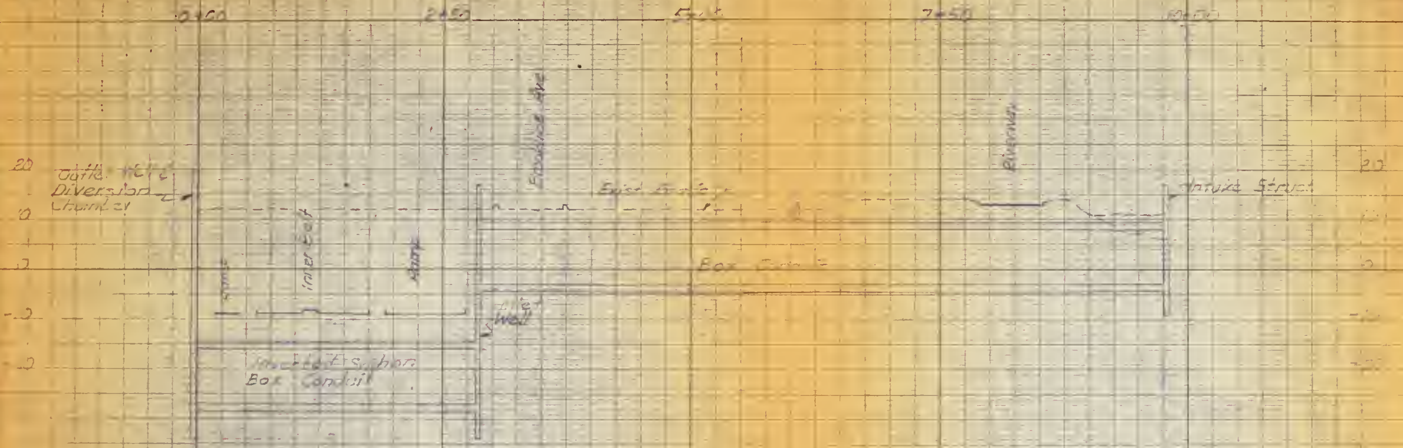
BOSTON, MASSACHUSETTS
1897–1900, 1903–1904, 1906–1951



U.S. DEPARTMENT OF COMMERCE
TECHNICAL PAPER NO. 25



LOCATION MAP OF PROPOSED CONDUIT



PROFILE OF PROPOSED CONDUIT

Horz. Scale 1" = 100'
Vert. Scale 1" = 20'

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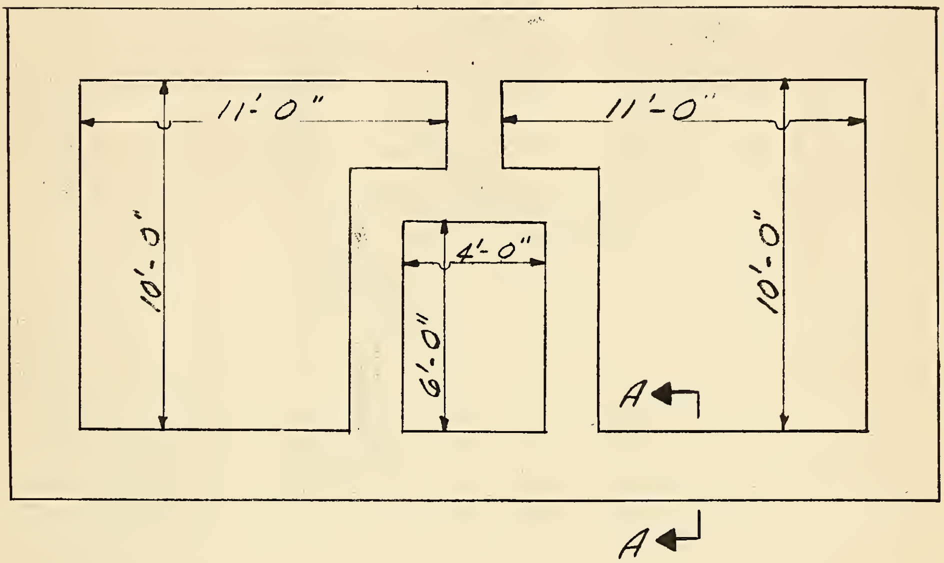
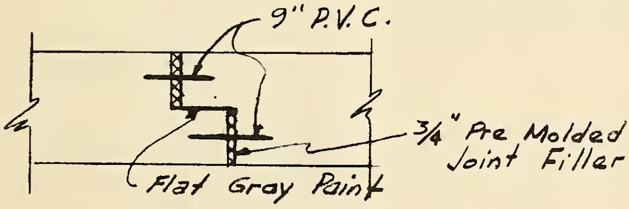
SUBJECT

EXHIBIT 5

PROPOSED CONDUIT



CROSS SECTION

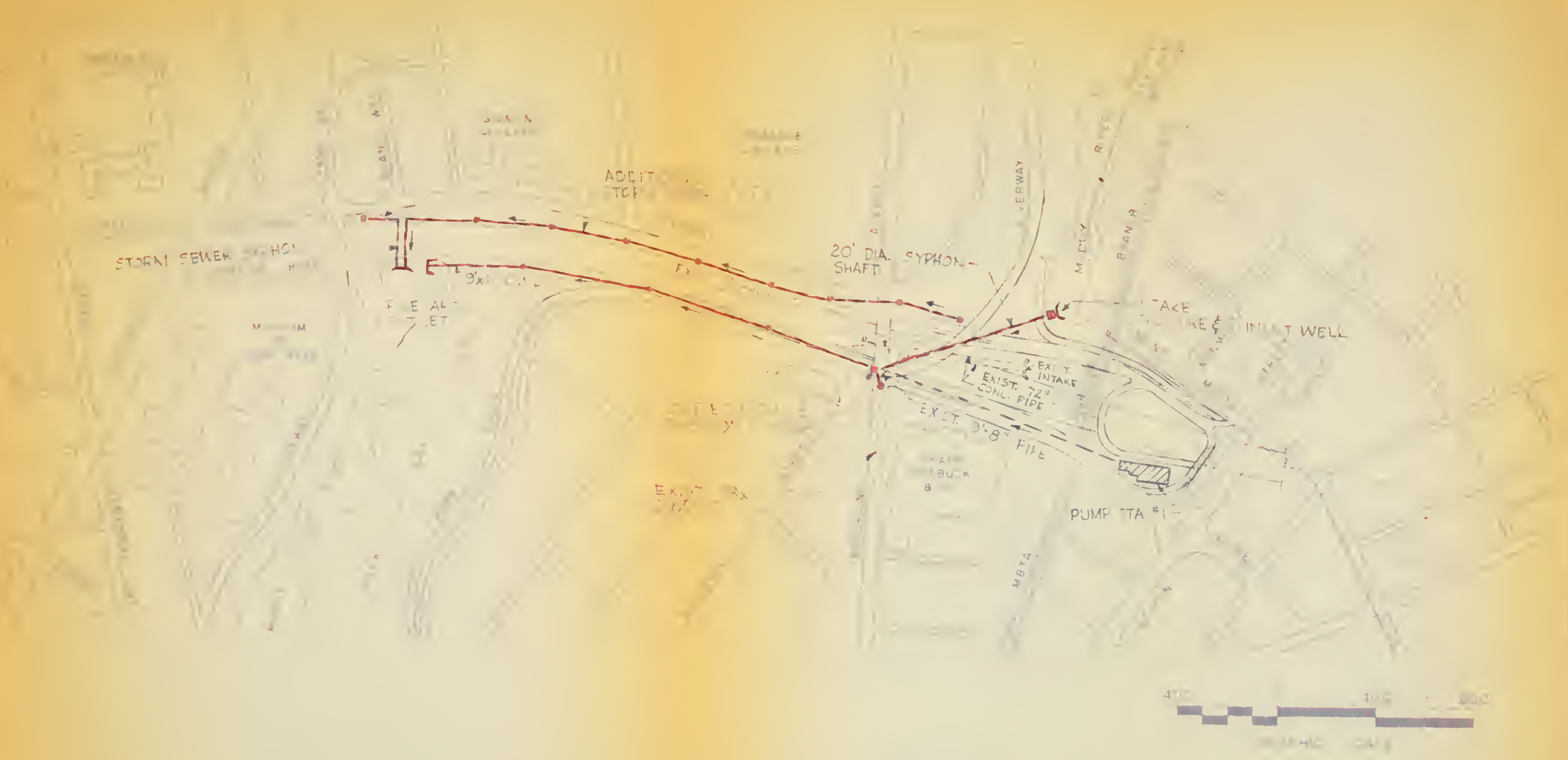


SECTION A-A

A = 91.25 SF
P = 42'

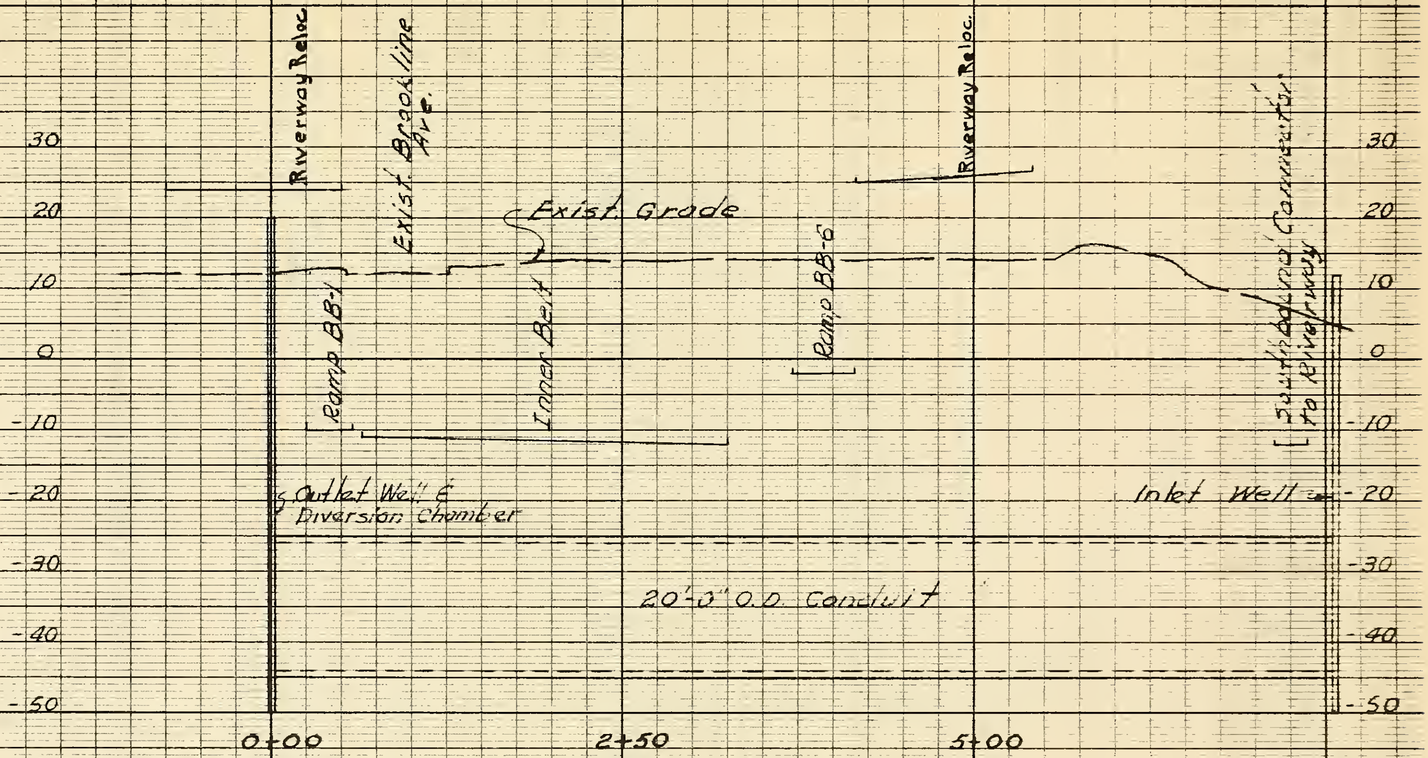
A = 24.0 SF
P = 20'

EXHIBIT [illegible]



LOCATION PLAN – [illegible] CONDUIT

EXHIBIT 7



PROFILE OF ALTERNATE CONDUIT

Horiz. Scale: 1" = 100'
Vert. Scale: 1" = 20'

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SHEET ____ OF ____
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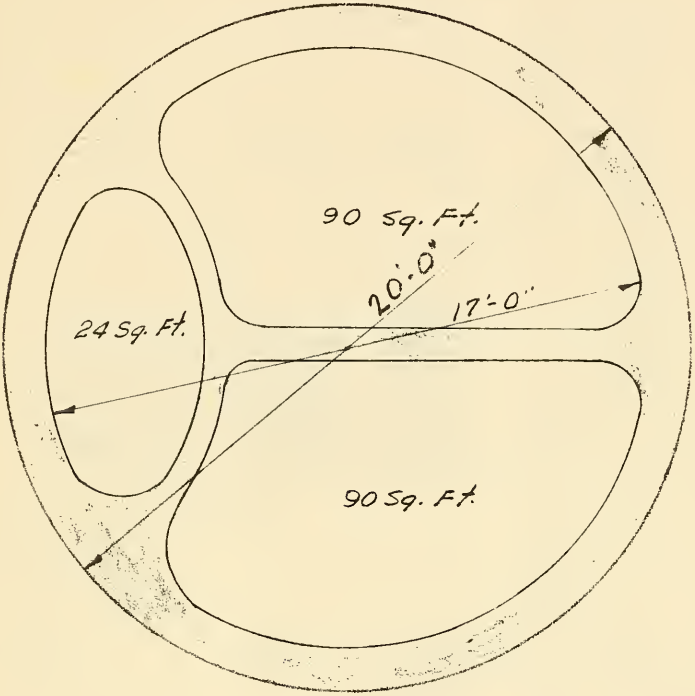
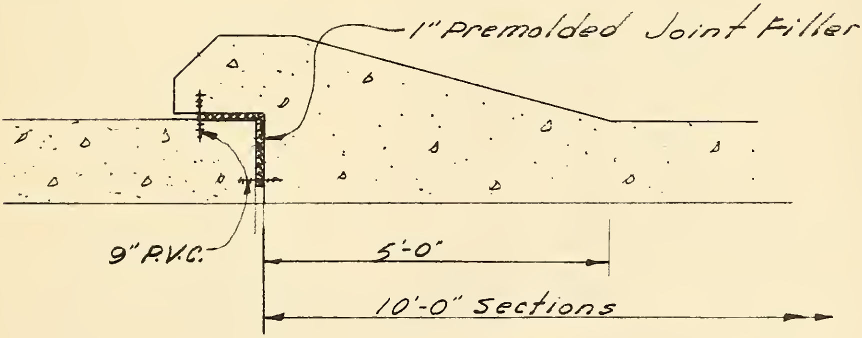
SUBJECT Tunnel Section for Syphon (Alternate Scheme)

EXHIBIT 8





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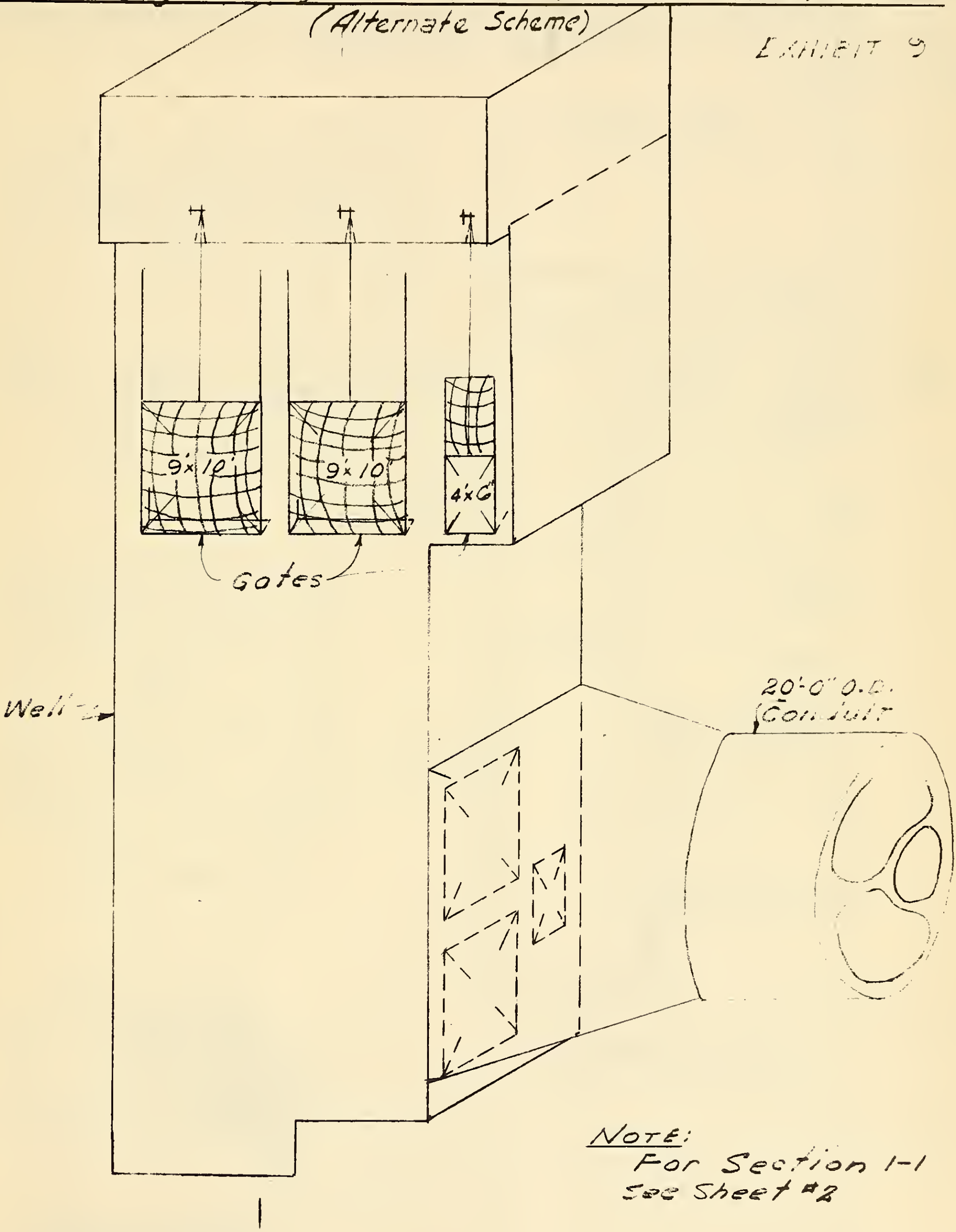
LOCATION Boston Inner Belt

SUBJECT Muddy River Syphon - Intake Structure - Sh. #1 (Alternate Scheme)

EXHIBIT 9



NOTE:
For Section 1-1
See Sheet #2

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DATE
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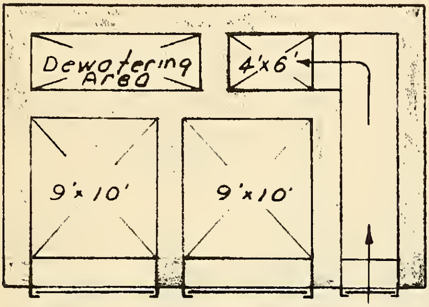
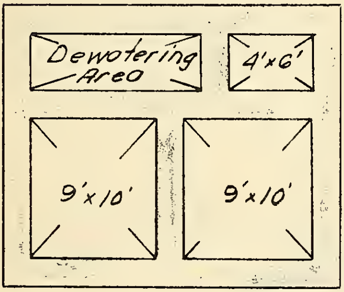
SUBJECT Muddy River Syphon - Intake Structure - SH #2
(Alternate Scheme)

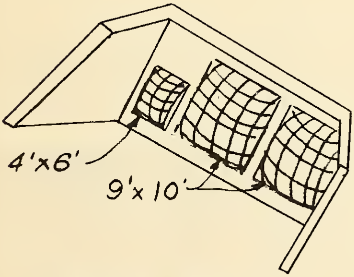
EXHIBIT 9a



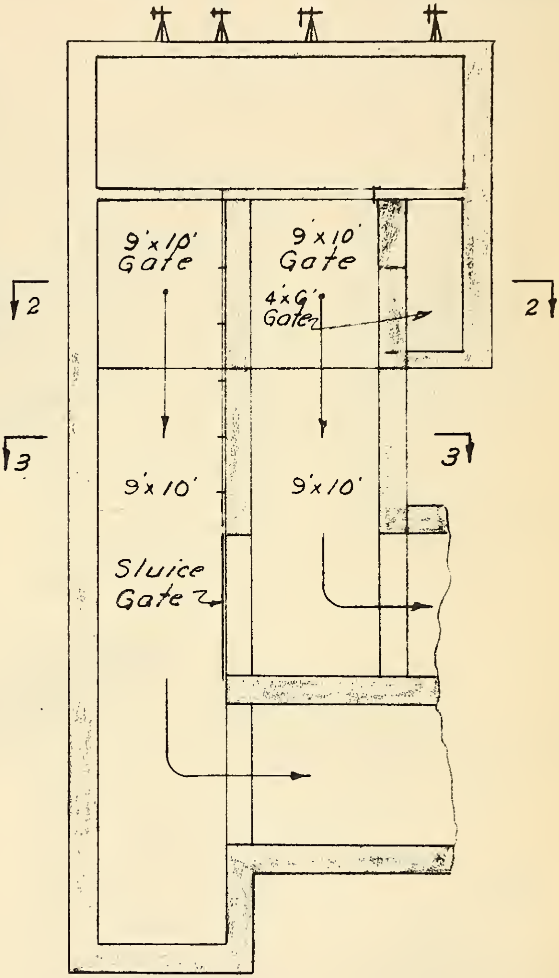
SECTION 2-2



SECTION 3-3



TRASH RACKS



SECTION 1-1

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SUBJECT OUTLET WELL & DIVERSION CHAMBER

PROPOSED SCHEME

EXHIBIT 10

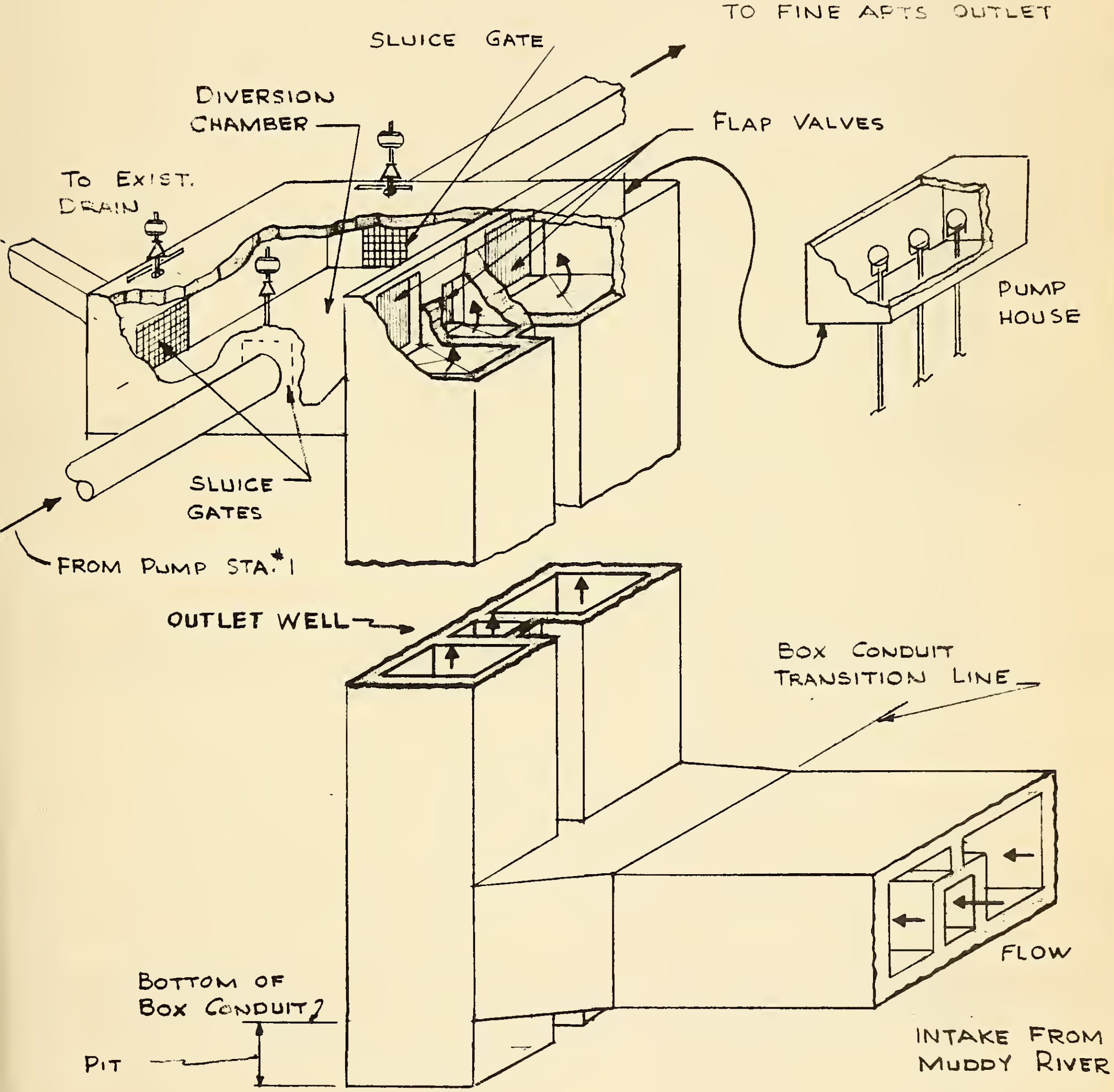
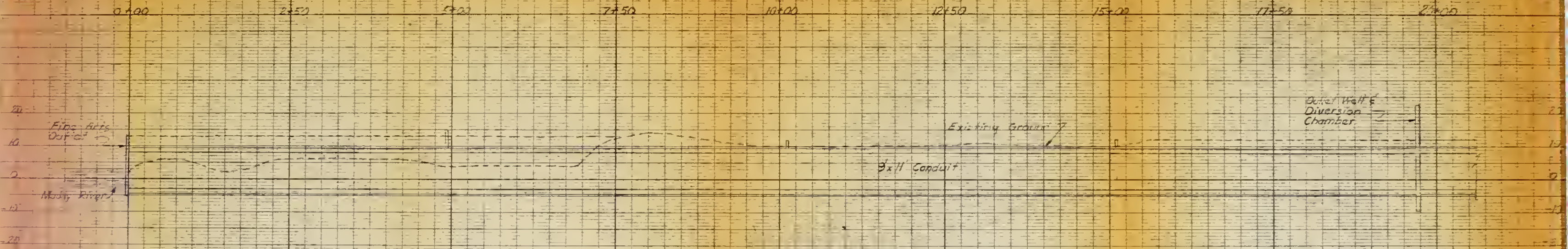


EXHIBIT II



PROFILE CONDUIT OUTLET

Scale: Horiz. 1"=100'
Vert. 1"=20'

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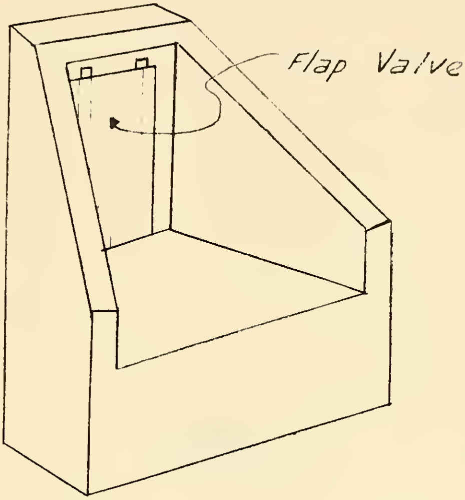
SUBJECT Fine Arts - Flap Outlet - Muddy River
(Alternate Scheme)

EXHIBIT 12



APPENDIX C

PROPOSED MODIFICATIONS OF THE STONY BROOK CONDUIT SYSTEM

INTERSTATE ROUTES 695 AND 95
CITY OF BOSTON

PROPOSED MODIFICATIONS OF THE STONY BROOK CONDUIT SYSTEM

TABLE OF CONTENTS

ITEM	PAGE
Scope of Report	1
Summary of Recommendations and Conclusions	2
Cost Analysis	6-10
Exhibits	

LIST OF EXHIBITS

EXHIBIT NO.	
1	Drainage Area
2	Location Map of Proposed Syphons & Protective Capping
3	Parker Street Plan & Profile of Proposed Syphon
4	Forsyth Street Plan & Profile of Proposed Syphon
5	Whittier Street Plan & Profile of Proposed Syphon
6	Detail of Typical Cross Sections Proposed
7	Detail of Typical Syphon
8	Detail of Proposed Capping of Existing 15'-6" x 17'-0" Conduits on Columbus Avenue
9	Detail of Proposed Capping of Existing 7'-0" x 7'-2 3/8" Conduit on Tremont Street

SCOPE OF REPORT

The proposed lines and grades of Interstate Routes 695 and 95 interfere in several locations with the Stony Brook conduit system.

This report summarizes the findings and recommendations of studies to determine the extent of this interference and the location, size and cost of inverted syphons and other structures that will be necessary for the maintenance of the drainage system at its present capacity.

SUMMARY OF RECOMMENDATIONS AND CONCLUSIONS

I. DRAINAGE AREA:

The drainage area tributary to the intercepted Stony Brook conduits is 8,800 acres. The population tributary to the flow of sanitary sewage in these conduits is approximately 100,000 permanent residents and 100,000 transients (1960 census figures).

II. CAPACITY OF PROPOSED INVERTED SYPHONS:

In all cases where existing conduits are intercepted it is proposed to replace these conduits by structures of equivalent capacity.

III. PROPOSED STRUCTURES AND PROTECTIVE CAPPING:

1. Inverted Syphons:

A. General Features of all Proposed Inverted Syphons:

Each structure would consist of; an intake diversion chamber, an intake transition conduit, an intake shaft, a syphon tube, an outlet shaft, an outlet transition conduit, and an outlet diversion chamber.

The intake diversion chamber would be built around the existing conduits beyond the limits of the proposed Inner Belt roadway. This chamber would accomodate the stop logs necessary for dewatering the syphon during

maintenance or repair operations.

The intake transition conduits, consisting of two 60' long parallel conduits equivalent to the existing conduits, would be constructed from the intake diversion chamber to the intake shaft.

The intake shaft would be a vertical well from the intake transition conduits down to the syphon tube. It would be a reinforced concrete structure divided into two openings with a cleanout pit extending below the invert of the syphon tube.

The syphon tube, consisting of two parallel box conduits of reinforced concrete under the proposed Inner Belt roadway, would connect the intake shaft and the outlet shaft.

The outlet shaft would be a vertical well from the syphon tube to the outlet transition conduit, similar to the inlet shaft except that it would not have cleanout pits.

The outlet transition conduit, similar to the inlet transition conduit, would be constructed from the outlet shaft to the outlet diversion chamber.

The outlet diversion chamber, similar to the inlet diversion chamber, would be built around the existing conduit. (See Exhibits 6 & 7).

B. The following inverted syphons are proposed:

1. Parker Street Syphon:

An inverted syphon consisting of twin 12'-0" x 13'-0"

box conduits, 243' long is proposed to replace the existing 12'-6" x 12'-0" double channel Stony Brook conduits. The approximate invert of the syphon tube would be elevation -35'. (See Exhibit 3).

2. Forsyth Street Syphon:

An inverted syphon consisting of twin 8'-6" x 11'-0" box conduits, 90' long is proposed to replace the existing 8'-3" x 10'-6" double channel Stony Brook conduits. The approximate invert of the syphon tube would be elevation -33'. (See Exhibit 4).

3. Whittier Street Syphon:

An inverted syphon consisting of twin 8'-6" x 10'-0" box conduits, 90' long is proposed to replace the existing 8'-3" x 9'-6" double channel Stony Brook conduits. The approximate invert of the syphon tube would be elevation -23'. (See Exhibit 5).

2. Protective Capping of Existing Conduits:

Concrete capping is proposed to protect existing conduits over which embankment sections of I-95 are planned.

Capping is proposed in the following areas, (See Exhibits 2, 8 & 9).

A. Capping of 450' of existing 7'-0" x 7'-2 3/8" single conduit on Tremont Street.

B. Capping 650' of existing 15'-6" x 17'-0" single conduit on Columbus Avenue.

IV. ESTIMATED COST OF PROPOSED STRUCTURES AND PROTECTIVE CAPPING:

Parker Street Syphon	$ 691,000
Forsyth Street Syphon	323,000
Whittier Street Syphon	283,000
Tremont Street Protective Capping	30,000
Columbus Avenue Protective Capping	179,000
TOTAL COST OF PROPOSED WORK	$1,506,000

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SHEET 6 OF —
DATE 3-11-65
LOCATION INNER BELT

SUBJECT STONY BROOK - SUMMARY OF SYHPONS

PARKER ST

DIVERSION CHAMBERS	50,000	
INLET SHAFT	69,000	
OUTLET SHAFT	62,000	
SYPHON TUBE	343,000	
TRANSITIONS	104,000	
	628,000	
CONTINGENCIES	63,000	$691,000

FORSYTH ST

DIVERSION CHAMBERS	43,000	
INLET SHAFT	47,900	
OUTLET SHAFT	41,500	
SYPHON TUBE	89,700	
TRANSITIONS	71,000	
	293,100	
CONTINGENCIES	29,900	323,000

WHITTIER ST

DIVERSION CHAMBERS	38,000	
INLET SHAFT	37,300	
OUTLET SHAFT	32,850	
SYPHON TUBE	80,000	
TRANSITIONS	69,000	
	257,150	
CONTINGENCIES	25,850	283,000
	TOTAL	$1,297,000

COMP. BY FJC
CHECK BY TJ
ACTIV. NO. 200

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 7 OF –
DATE 3-11-65
LOCATION INNER BELT

SUBJECT STONY BROOK - PROTECTIVE CAPPING

TREMONT STREET - (7'-0" x 7'-2 3/8")

Excavation: 6' x 16'/27 = 3.55 @ $\$2^{\underline{50}}$ = 8.90

* Concrete & Forms: 1' x 16'/27 x $\$80^{\underline{00}}$ = 47.40

Back fill: 5' x 16'/27 x $\$1^{\underline{25}}$ 3.70

\$ 60.00/LF

450' x \$60 = 27,000

CONTINGENCIES 3,000

\$ 30,000

COLUMBUS AVE (15'-6" x 17'-0")

Excavation: 6' x 32'/27 @ $\$2^{\underline{50}}$ = 17.75

* Concrete: 38' x 2'/27 @ $80^{\underline{00}}$ = 225.60

Back fill: 4' x 32/27 @ $\$1^{\underline{25}}$ 5.93

\$ 249.28/LF

650' @ \$250 = 162,500

Contingencies 16,500

\$ 179,000

* NOTE:
The cost of the premolded filler is included in the estimated price of the Concrete & Forms.

COMP. BY FJC
CHECK BY PJ
ACTIV. NO. 200

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 8 OF –
DATE 3-11-65
LOCATION INNER BELT

SUBJECT Stony Brook - Parker Street Syphon

DIVERSION CHAMBERS (2)

Chambers	32,000
Manholes & Stoplogs	12,000
TIE In to Exist. Conduits	6,000
	50,000

INLET SHAFT

Excavation: 1200 yds³ @ $5.00 =	6,000
Sheathing: 5700 sq.ft. @ $4.00 =	23,000
Concrete & Forms: 450 yds @ $80.00 =	36,000
Manholes & Misc.	4,000
	$ 69,000

OUTLET SHAFT

Excavation: 1000 yds³ x $5.00 =	5,000
Sheathing: 5000 s.f. @ $4.00 =	20,000
Concrete & Forms: 410 yds @ $80.00 =	33,000
Manholes & Misc.	4,000
	$ 62,000

SYPHON TUBE (INVERT El. -35')

Excavation: 63 yds @ $5.00 = $315
Sheathing: 110 sF @ $4.00 = 440
Concrete & Forms: 8.18 yds @ $80.00 = 655
$ 1410/LF

Tube 243 LF @ $1410.00 = $343,000

TRANSITION (2 @ 60' = 120')

Excavation: 25.2 yds @ $2.50 = 63
Sheathing: 50 s.f. @ $3.00 = 150
Concrete & Forms: 8.18 x $80.00 = 655
$ 868/LF

120 LF x $868 $ 104,000

COMP. BY FJC
CHECK BY PJ
ACTIV. NO. 200

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 9 OF —
DATE 3-11-65
LOCATION INNER BELT

SUBJECT Stony Brook - Forsyth Street Syphon

DIVERSION CHAMBERS (2)

Chambers	25,000
Manholes & Stop Logs	12,000
Tie In to Exist. conduits	6,000
	43,000

INLET SHAFT (56')

Excavation: 700 yd³ x \$5.00	3,500
Sheathing: 4500 S.F. @ \$4.00	18,000
Concrete & Forms: 280 yd³ x \$80.00	22,400
Manholes & Misc:	4,000
	\$ 47,900

OUTLET SHAFT (48')

Excavation: 580 yd³ x \$5.00	2,900
Sheathing: 3900 x \$4.00	15,600
Concrete & Forms: 238 yd³ x \$80.00	19,000
Manholes & Misc:	4,000
	\$ 41,500

SYPHON TUBE (90') INVERT El. -33'

Excavation: 40 yds x \$5.00 =	200	
Sheathing: 100 SF @ \$4.00 =	400	
Concrete & Forms: 4.96 x \$80.00	397	
	997/LF	
Tube 90' x \$997		= \$ 89,700

TRANSITION (2 x 60 = 120')

Excavation: 18 yds @ \$2.50	45.00	
Sheathing: 50 SF @ \$3.00	150.00	
Concrete & Forms: 4.96 x \$80.00	397.00	
	592.00/LF	
120 x \$592		\$ 71,000

COMP. BY FJC
CHECK BY PJ
ACTIV. NO. 200

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 10 OF –
DATE 3-11-65
LOCATION INNER BELT

SUBJECT Stony Brook – Whittier Street Syphon

DIVERSION CHAMBERS (2)

Chambers		20,000
Manholes & Stop Logs		12,000
Tie In to Exist. Conduits		6,000
		38,000
INLET SHAFT (44')		
Excavation: 500 yd³ @ $5.00		2,500
Sheathing: 3500 SF @ $4.00		14,000
Concrete & Forms: 210 yds³ @ $80.00		16,800
Manholes & Misc:		4,000
		37,300
OUTLET SHAFT (38')		
Excavation: 410 yds³ @ $5.00		2050
Sheathing: 3100 S.F. @ $4.00		12,400
Concrete & Forms: 180 yds³ @ $80.00		14,400
Manholes & Misc:		4,000
		32,850
SYPHON TUBE (90") INVERT El. -23'		
Excavation: 33 yds @ $5.00 =	165	
Sheathing: 86 SF @ $4.00 =	344	
Concrete & Forms: 4.73 yd³ @ $80.00 =	379	
	$888	
Tube 90' @ $888		= 80,000
TRANSITION (2 × 60' = 120') =		
Excavation: 17 yds @ $2.50 =	143	
Sheathing: 50 SF @ $3.00 =	150	
Concrete & Forms 4.73 yd³ @ $80.00 =	379	
	$572	
120' @ $572	=	69,000

16909

EXHIBIT 1

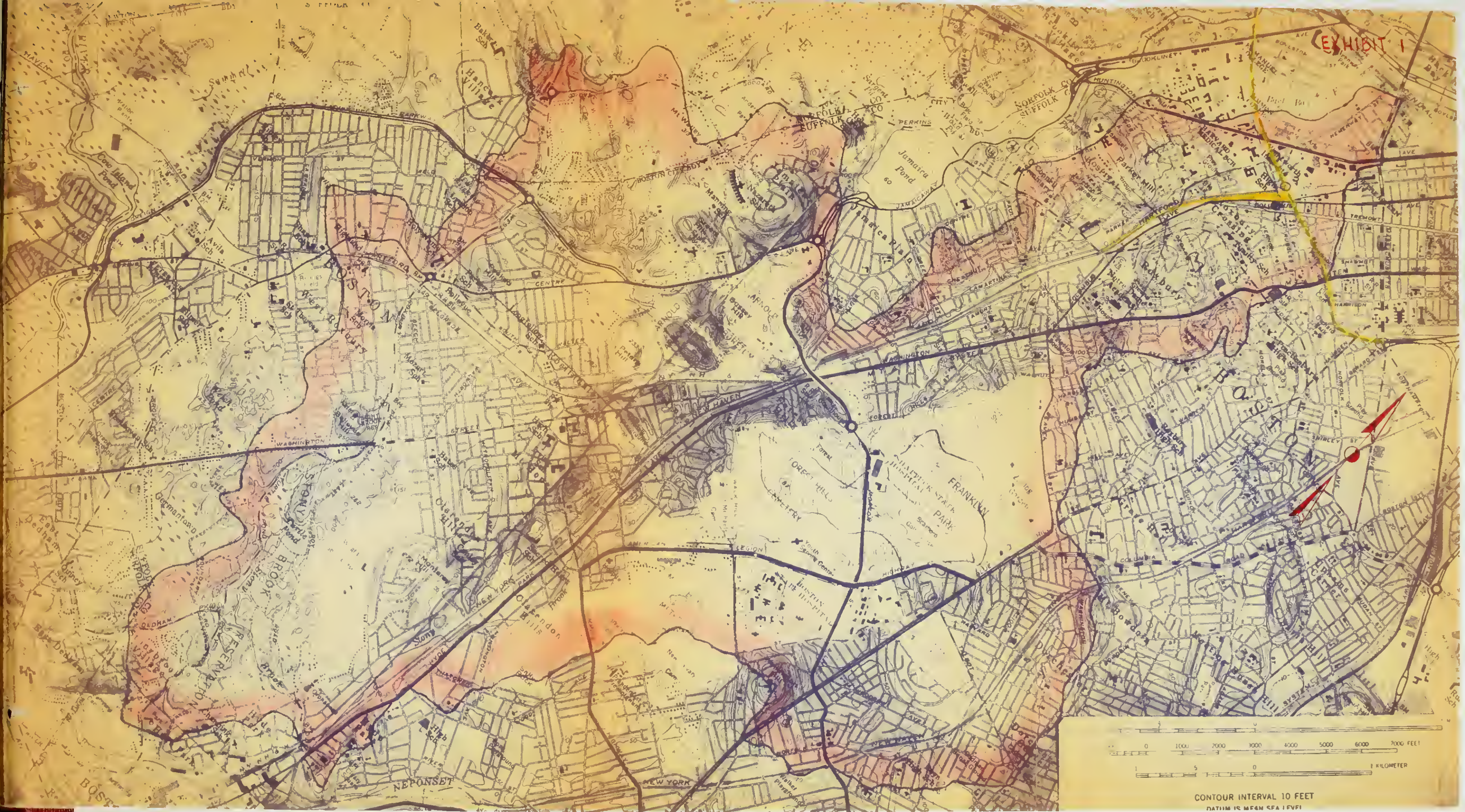
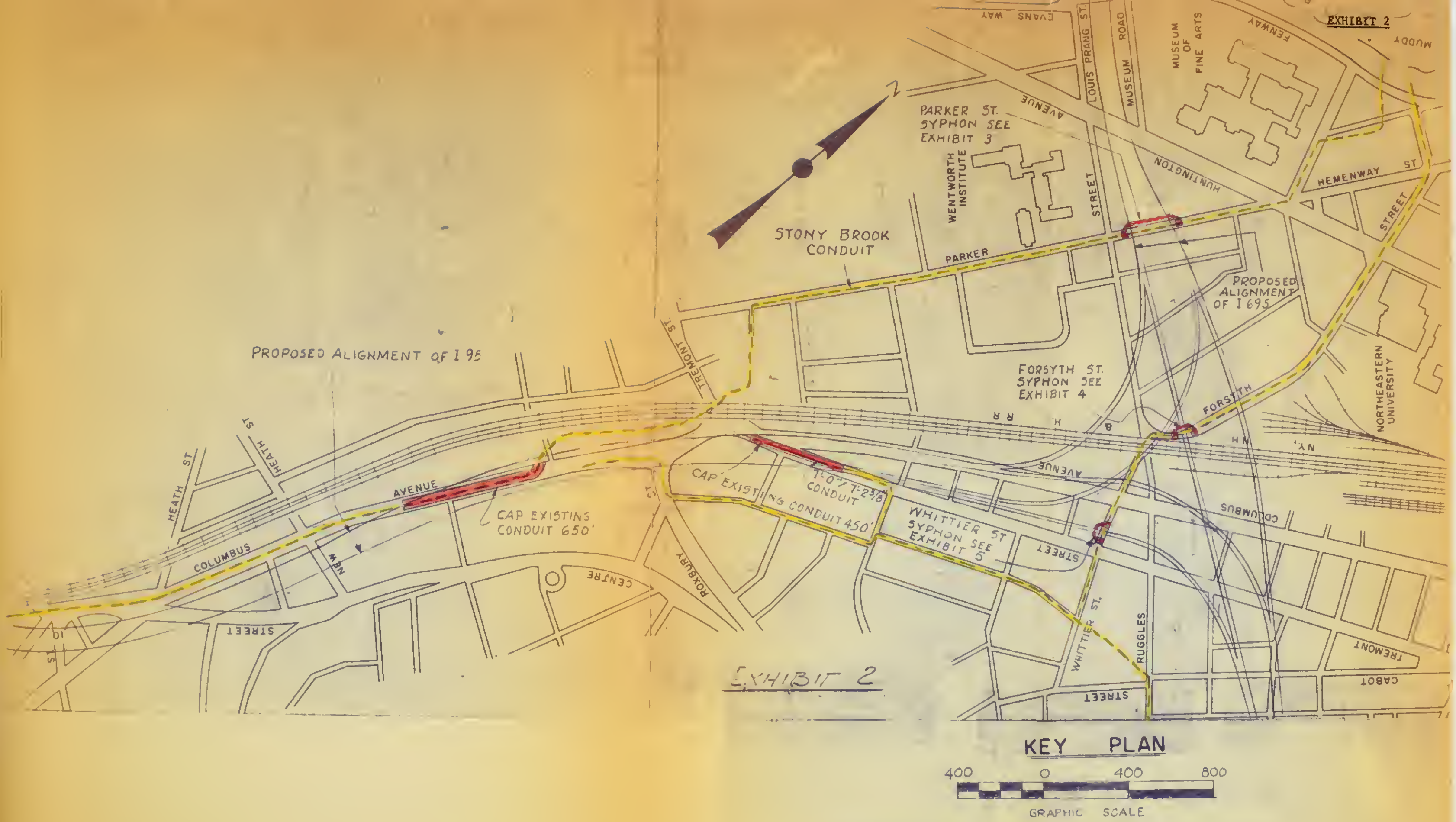
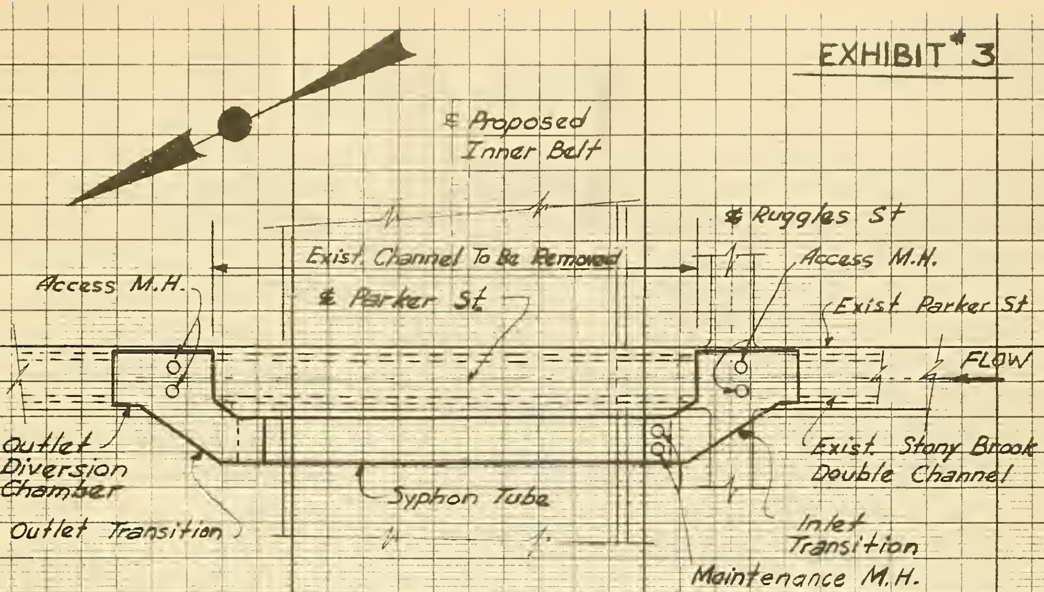

BOSTON
West Roxbury
Roxbury
Jamaica Plain
Jamaica Pond
Franklin Park
Forest Hills Cemetery
Arnold Arboretum
Stony Brook Reservation
Dorchester
Neponset
Cow Island Pond
Hyde Park
Parker Hill
Mission Hill
Dedham
Washington
New Haven
New York
Centre
Huntington
Tremont
Columbia
Norfolk Co
Suffolk Co
Perkins
Jamaicaway
Boston City Hospital
Harvard Medical Sch
Mattapan
Oakland
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL
0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

EXHIBIT 2



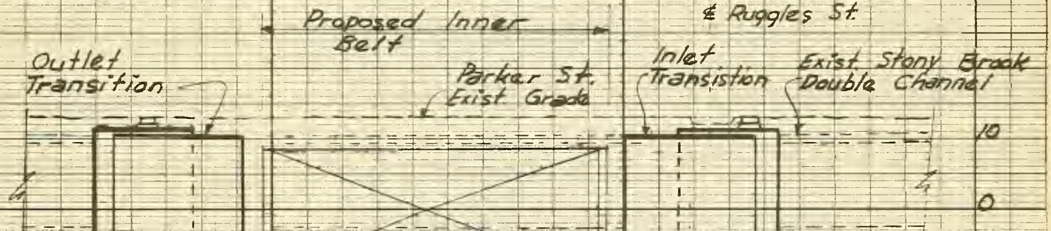
LOCATION MAP OF PROPOSED SYPHONS & PROTECTIVE CAPPING

EXHIBIT # 3



PLAN

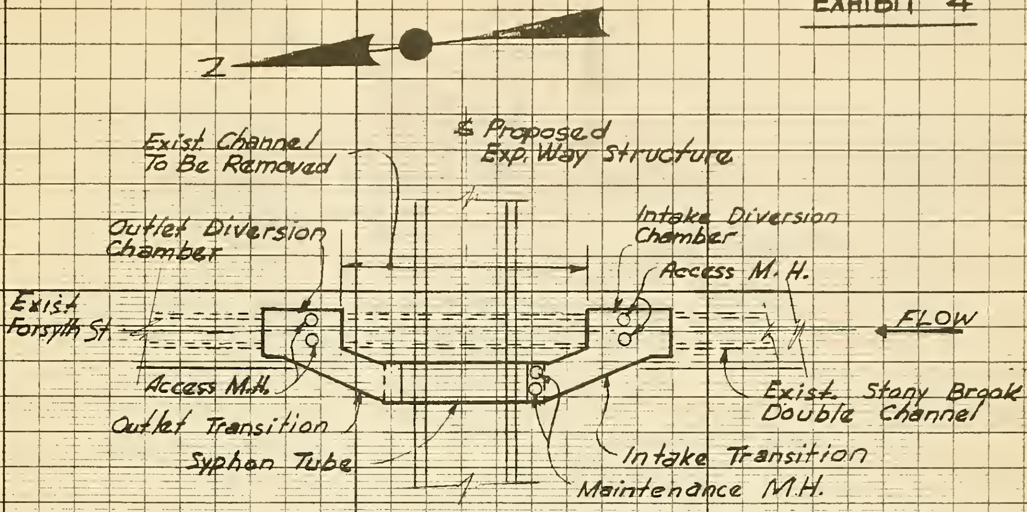
Scale ; 1" = 100'



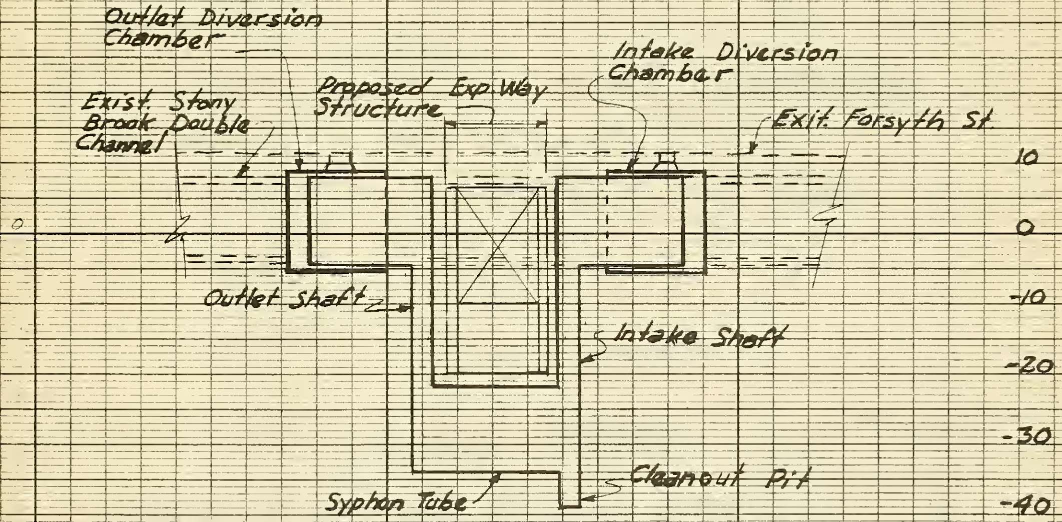
PROFILE OF PROPOSED PARKER ST. SYPHON

Scale : Horz. 1" = 100'
Vert. 1" = 20'

EXHIBIT #4



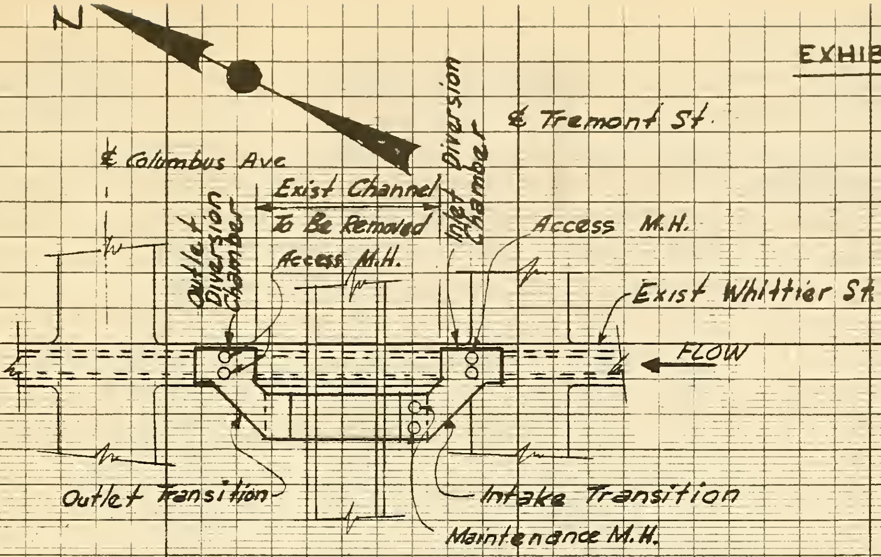
PLAN
Scale: 1" = 100'



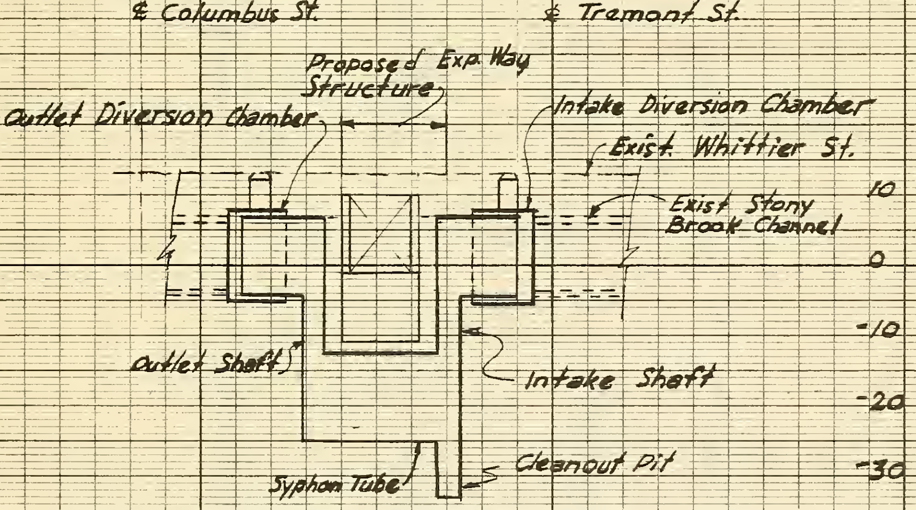
PROFILE OF PROPOSED FORSYTH ST. SYPHON

Scale: Horiz. 1" = 100'
Vert. 1" = 20'

EXHIBIT # 5



PLAN
Scale 1" = 100'



PROFILE OF PROPOSED WHITTIER ST SYPHON
Scale: Vert. 1" = 20'
Horiz. 1" = 100'

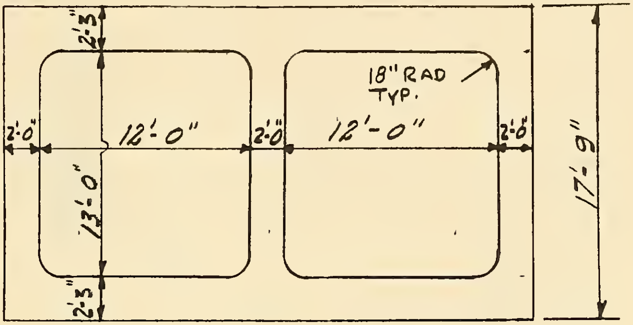
COMP. BY J.B.
CHECK BY FJC
ACTIV. NO. 200

JOHN CLARKESON
CONSULTING ENGINEER

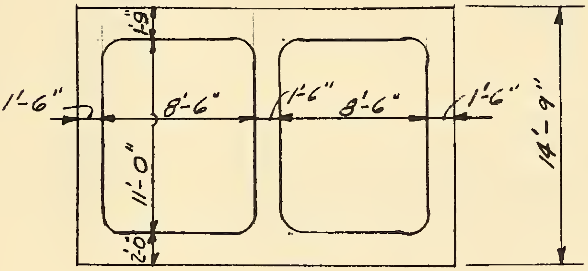
SHEET – OF –
DATE 3-11-65
LOCATION INNER BELT

SUBJECT

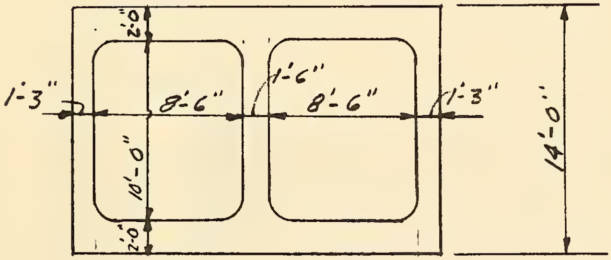
EXHIBIT 6



TYPICAL CROSS SECTION
PARKER ST. SYPHON



TYPICAL CROSS SECTION
FORSYTH ST. SYPHON



TYPICAL CROSS SECTION
WHITTIER ST. SYPHON

DETAIL OF TYPICAL CROSS SECTIONS PROPOSED

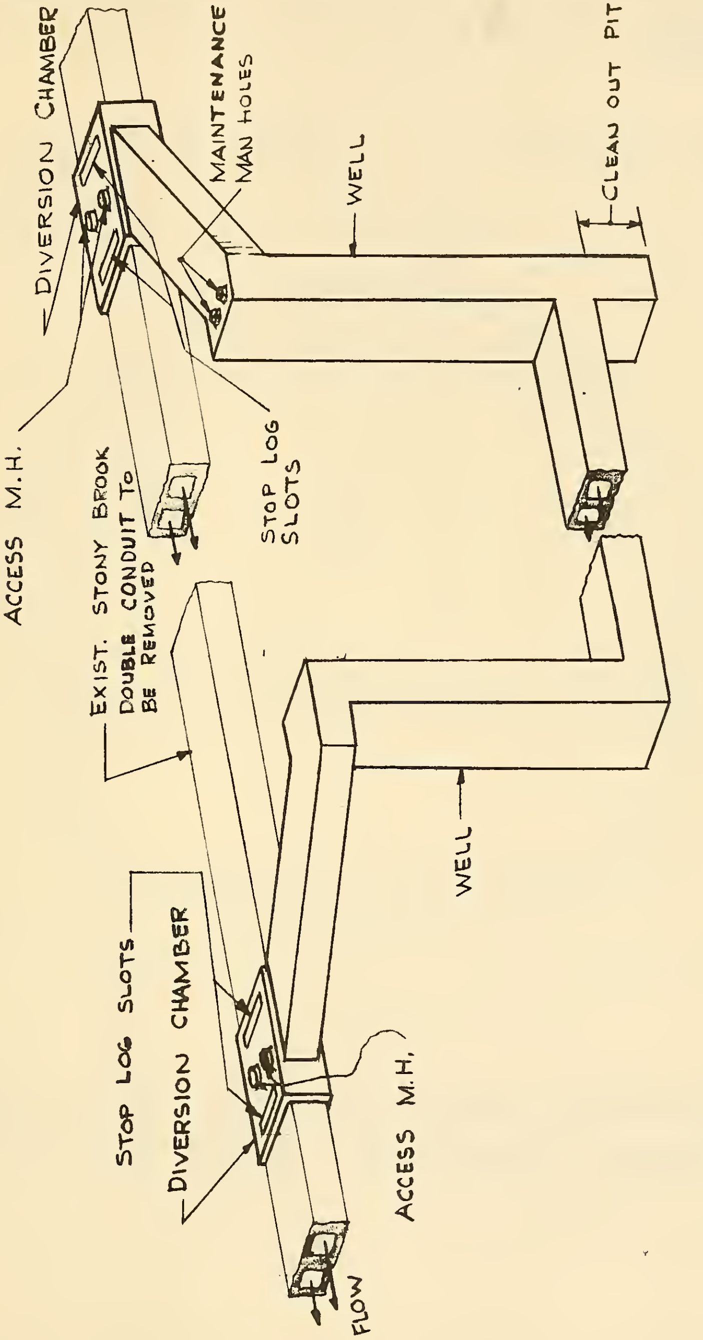
COMP. BY J.B.
CHECK BY FJC
ACTIV. NO.

JOHN CLARKESON
CONSULTING ENGINEER

SHEET – OF –
DATE 3-9-65
LOCATION INNER BELT

SUBJECT

EXHIBIT 7



DETAIL OF TYPICAL SYPHON

81088

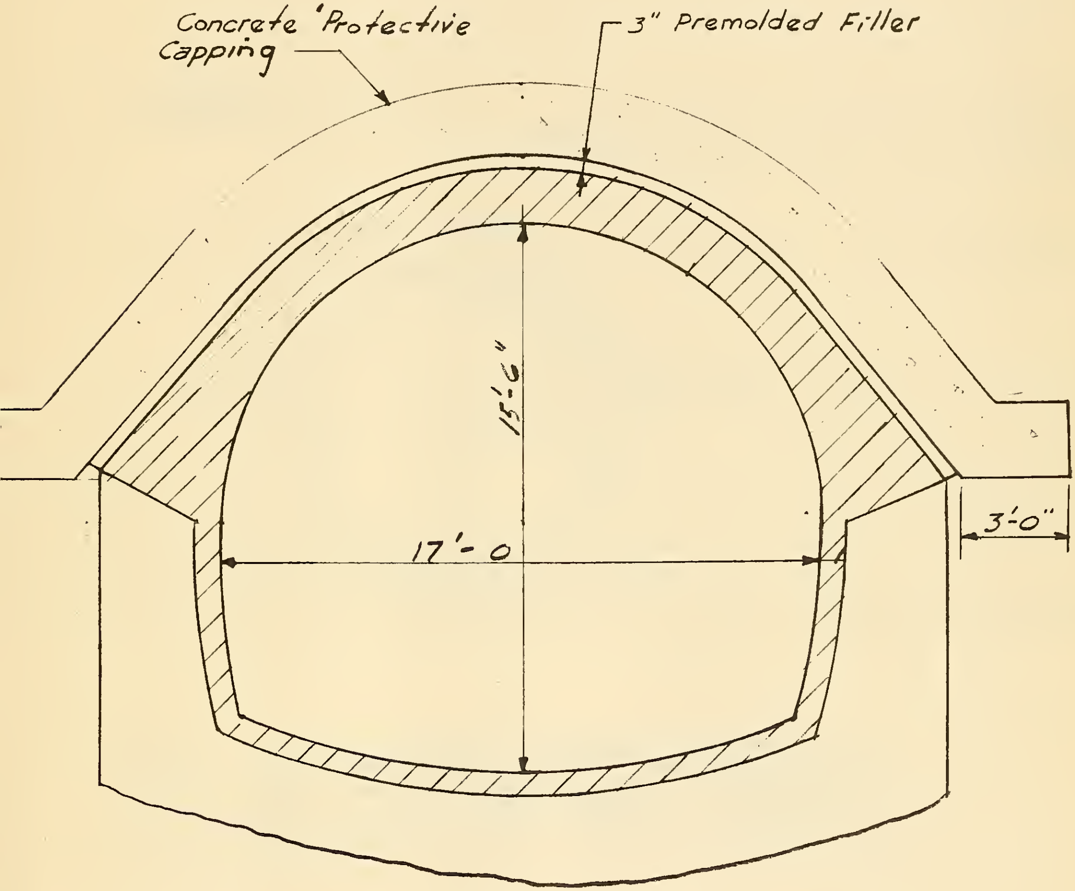
COMP. BY J.B.
CHECK BY FJC
ACTIV. NO. 200

JOHN CLARKESON
CONSULTING ENGINEER

SHEET - OF -
DATE 3-10-65
LOCATION INNER BELT

SUBJECT

EXHIBIT 8



DETAIL OF PROPOSED CAPPING OF EXISTING 15'-6" x 17'-0" CONDUIT ON COLUMBUS AVENUE

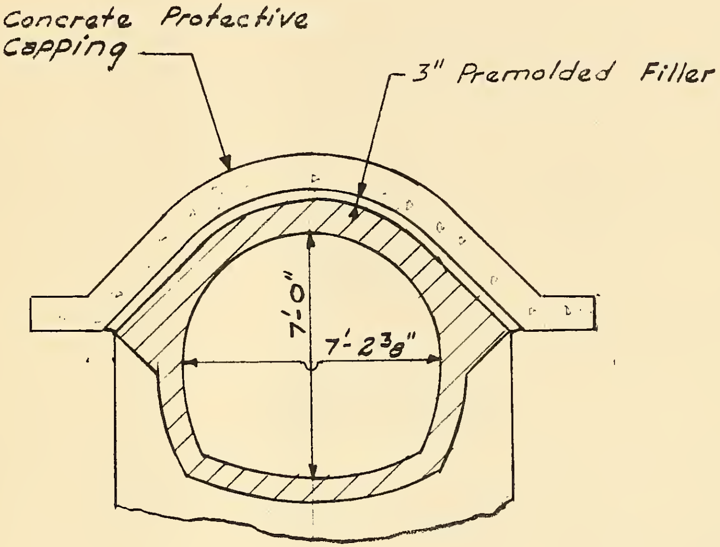
COMP. BY J.B.
CHECK BY TJC
ACTIV. NO. 200

JOHN CLARKESON
CONSULTING ENGINEER

SHEET — OF —
DATE 3-10-65
LOCATION INNER BELT

SUBJECT

EXHIBIT 9



DETAIL OF PROPOSED CAPPING OF EXISTING
7'-0" x 7'-2 3/8" CONDUIT ON TREMONT STREET

81899

APPENDIX D

DETAILED COST DATA

COMP. BY L.E.
CHECK BY
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 1 OF
DATE 4/22/65
LOCATION

SUBJECT Cost Section 1 As Presented

Cost Section 1

ITEM	Scheme "A"	Scheme "B"	Scheme "C"
Depressed Roadway	10,820,000	10,407,000	15,335,000
Elevated Roadway	8,196,000	6,287,000	356,000
Embankment Roadway	85,000	85,000	56,000
Cross Road Structures	615,000	785,000	1,229,000
Railroad Structures	-	-	-
Access Ramps	1,057,000	1,101,000	605,000
Frontage Roads	293,000	293,000	284,000
Utilities	1,053,000	948,000	893,000
Major Hydraulic Structures	548,000	548,000	1,073,000
Roadway Drainage	465,000	465,000	465,000
Lighting	150,000	150,000	150,000
Misc.—Signs, Signals, Landscaping, Guard Rails, Traffic Contr. Etc	150,000	150,000	150,000
Contingencies & Engineering	2,343,000	2,122,000	2,060,000
Total Construction	25,775,000	23,341,000	22,656,000
Demolition Cost	272,000	238,000	272,000
TOTAL	26,047,000	23,579,000	22,928,000

COMP. BY L.E.
CHECK BY
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 2 OF
DATE 4/23/65
LOCATION

SUBJECT Cost Section 1 Modification IX

ITEM	Modification IX with Scheme "A"	Modification IX with Scheme "B"	Modification IX with Scheme "C"
Depressed Roadway	6,288,000	5,816,000	8,078,000
Elevated Roadway	9,035,000	8,373,000	2,519,000
Embankment Roadway	269,000	249,000	483,000
Cross Road Structures	837,000	1,190,000	1,348,000
Railroad Structures	—	—	—
Access Ramps	1,057,000	1,101,000	369,000
Frontage Roads	293,000	293,000	284,000
Utilities	889,000	851,000	654,000
Major Hydraulic Structures	366,000	366,000	556,000
Roadway Drainage	465,000	465,000	465,000
Lighting	150,000	150,000	150,000
Misc.—Signs, Signals, Landscaping Guard Rails Traffic Contr. Etc	150,000	150,000	150,000
Contingencies & Engineering	1,980,000	1,900,000	1,506,000
Total Construction	21,779,000	20,904,000	16,562,000
Demolition Cost	272,000	238,000	272,000
TOTAL	22,051,000	21,142,000	16,834,000

COMP. BY L.E.
CHECK BY
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 3 OF
DATE 4/22/65
LOCATION

SUBJECT Cost Section 1 Modification X

ITEM	Modification X with Scheme A	Modification X with Scheme B	Modification X with Scheme C	
DEPRESSED ROADWAY	10,820,000	10,407,000	15,335,000	
ELEVATED ROADWAY	8,196,000	6,287,000	356,000	
EMBANKMENT ROADWAY	85,000	85,000	56,000	
CROSS ROAD STRUCTURES	615,000	785,000	1,229,000	
RAILROAD STRUCTURES	–	–	–	
ACCESS & RAMPS	1,061,000	1,105,000	609,000	
FRONTAGE ROADS	269,000	269,000	260,000	
UTILITIES	1,052,000	947,000	892,000	
MAJOR HYDRAULIC STRUCTURES	548,000	548,000	1,073,000	
ROADWAY DRAINAGE	465,000	465,000	465,000	
LIGHTING	150,000	150,000	150,000	
MISC.–SIGNS, SIGNALS, LANDSCAPING GUARD RAILS TRAFFIC CONTR. ETC	150,000	150,000	150,000	
CONTINGENCIES & ENGINEERING	2,341,000	2,120,000	2,058,000	
TOTAL CONSTRUCTION	25,752,000	23,318,000	22,633,000	
DEMOLITION COST	270,000	270,000	270,000	
TOTAL	26,022,000	23,588,000	22,903,000	

COMP. BY L.E. ✓
CHECK BY
ACTIV. NO

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 4 OF
DATE 4/22/65
LOCATION

SUBJECT Cost Section 1 Modification XI

ITEM	Modification XI with Scheme A	Modification XI with Scheme B	Modification XI with Scheme C
Depressed Roadway	10,820,000	10,407,000	15,335,000
Elevated Roadway	8,196,000	6,287,000	356,000
Embankment Roadway	95,000	85,000	56,000
Cross Road Structures	615,000	785,000	1,229,000
Railroad Structures	—	—	—
Access Ramps	894,000	977,000	442,000
Frontage Roads	222,000	222,000	213,000
Utilities	1,042,000	938,000	882,000
Major Hydraulic Structures	548,000	548000	1,073,000
Roadway Drainage	465,000	465,000	465,000
Lighting	150,000	150,000	150,000
Misc.–Signs, Signals, Landscaping Guard Rails & Traffic Contr. Etc	150,000	150,000	150,000
Contingencies & Engineering	2,319,000	2,101,000	2,035,000
Total Construction	25,506,000	23,115,000	22,386,000
Demolition Cost	280,000	280,000	280,000
TOTAL	25,786,000	23,395,000	22,666,000

COMP. BY L.E.
CHECK BY
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 5 OF
DATE 4/22/65
LOCATION

SUBJECT COST SECTION 1 Modification XII

ITEM	Modification XII with Scheme 'A'	Modification XII with Scheme "B"	Modification XII with Scheme "C"
DEPRESSED ROADWAY	10,820,000	10,407,000	15,335,000
ELEVATED ROADWAY	8,196,000	6,287,000	356,000
EMBANKMENT ROADWAY	85,000	85,000	56,000
CROSS ROAD STRUCTURES	968,000	1,138,000	1,582,000
RAILROAD STRUCTURES	—	—	—
ACCESS RAMPS	1,057,000	1,101,000	605,000
FRONTAGE ROADS	875,000	875,000	866,000
UTILITIES	1,100,000	995,000	940,000
MAJOR HYDRAULIC STRUCTURES	716,000	716,000	1,241,000
ROADWAY DRAINAGE	490,000	490,000	490,000
LIGHTING	171,000	171,000	171,000
MISC.–SIGNS, SIGNALS, LANDSCAPING GUARD RAILS TRAFFIC CONTR. ETC	240,000	240,000	240,000
CONTINGENCIES & ENGINEERING	2,472,000	2,251,000	2,188,000
TOTAL CONSTRUCTION	27,190,000	24,756,000	24,070,000
DEMOLITION COST	272,000	238,000	272,000
TOTAL	27,462,000	24,994,000	24,342,000

SUBJECT Cost Section 2 As Presented

Cost Section 2 ITEM	Scheme "A"	Scheme "B"	Scheme "C"
Depressed Roadway	6,554,000	6,956,000	6,554,000
Elevated Roadway	5,883,000	5,401,000	4,900,000
Embankment Roadway	217,000	134,000	217,000
Cross Road Structures	852,000	852,000	852,000
Railroad Structures	1,330,000	1,330,000	1,330,000
Access Ramps	26,000	7000	26,000
Frontage Roads	118,000	387,000	118,000
Utilities	749,000	753,000	700,000
Major Hydraulic Structures	1,153,000	1,483,000	1,233,000
Roadway Drainage	190,000	190,000	190,000
Lighting	100,000	100,000	100,000
Misc.-Signs, Signals, Landscaping, Guard Rails Traffic Contr. Etc.	181,000	181,000	181,000
Contingencies & Engineering	1,735,000	1,777,000	1,640,000
Total Construction	19,088,000	19,551,000	18,041,000
Demolition Cost	198,000	198,000	198,000
TOTAL	19,286,000	19,749,000	18,239,000

SHEET 7 OF
DATE
LOCATION

COMP. BY
CHECK BY
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SUBJECT Cost Section 2 Modification VIII

ITEM	Modification VIII with with Scheme "A"	Modification VIII with with Scheme "B"	Modification VIII with with Scheme "C"
Depressed Roadway	6,554,000	6,956,000	6,554,000
Elevated Roadway	5,883,000	5,401,000	4,900,000
Embankment Roadway	217,000	134,000	217,000
Cross Road Structures	1,786,000	1,786,000	1,786,000
Railroad Structures	1,330,000	1,330,000	1,330,000
Access Ramps	44,000	25,000	44,000
Frontage Roads	457,000	726,000	457,000
Utilities	813,600	818,000	764,000
Major Hydraulic Structures	1,153,000	1,483,000	1,233,000
Roadway Drainage	190,000	190,000	190,000
Lighting	100,000	100,000	100,000
Misc.-Signs, Signals, Landscaping Guard Rails Traffic Contr. Etc	181,000	181,000	181,000
Contingencies & Engineering	1,871,000	1,913,000	1,776,000
Total Construction	20,580,000	21,043,000	19,532,000
Demolition Cost	268,000	268,000	268,000
TOTAL	20848,000	21,311,000	19,800,000

COMP. BY /
CHECK BY
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 8 OF
DATE
LOCATION

SUBJECT Cost Section 3 As Presented

Cost Section 3

ITEM	Schemes "A" & "B"	Scheme "C"
Depressed Roadway	15,802,000	11,517,000
Elevated Roadway	—	—
Embankment Roadway	—	—
Cross Road Structures	899,000	962,000
Railroad Structures	—	—
Access Ramps	—	—
Frontage Roads	108,000	108,000
Utilities	841,000	629,000
Major Hydraulic Structures	1,484,000	1,484,000
Roadway Drainage	320,000	320,000
Lighting	386,000	91,000
Misc.—Signs, Signals, Landscaping, Guard Rails, Traffic Contr. Etc.	1,723,000	512,000
Contingencies & Engineering	2,156,000	1,557,000
Total Construction	23,719,000	17,130,000
Demolition Cost	25,000	25,000
TOTAL	23,744,000	17,155,000

COMP. BY ✓
CHECK BY
ACTIV. NO.

CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 9 OF
DATE
LOCATION

SUBJECT Cost Section 3 Modification III

ITEM		Modification III with Schemes "A" & "B"		Modification III with Scheme "C"
Depressed Roadway		2,959,000		2,612,000
Tunnel		12,920,000		12,920,000
Embankment Roadway		—		—
Cross Road Structures		718,000		781,000
Railroad Structures		—		—
Access Ramps		—		—
Frontage Roads		170,000		170,000
Utilities		838,000		824,000
Major Hydraulic Structures		1,454,000		1,454,000
Roadway Drainage		320,000		320,000
Lighting		237,000		353,000
Misc.—Signs, Signals, Landscaping Guard Rails Traffic Contr. Etc		2,819,000		2,889,000
Contingencies & Engineering		2,244,000		2,232,000
Total Construction		24,679,000		24,555,000
Demolition Cost		25,000		25,000
Total		24,704,000		24,580,000

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CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 10 OF
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SUBJECT Cost Section III Modification V

ITEM	Modification V with Schemes A&B	Modification V with Scheme C		
Depressed Roadway	15,802,000	11,517,000		
Elevated Roadway	–	–		
Embankment Roadway	–	–		
Cross Road Structures	1,040,000	1,103,000		
Railroad Structures	–	–		
Access Ramps	–	–		
Frontage Roads	134,000	134,000		
Utilities	849,000	638,000		
Major Hydraulic Structures	1,484,000	1,484,000		
Roadway Drainage	320,000	320,000		
Lighting	386,000	41,000		
Misc.–Signs, Signals, Landscaping Guard Rails Traffic Contr. Etc	1,723,000	512,000		
Contingencies & Engineering	2,174,000	1,575,000		
Total Construction	23,912,000	17,324,000		
Demolition Cost	25,000	25,000		
TOTAL	23,937,000	17,349,000		

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CLARKESON ENGINEERING CO., INC.
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SUBJECT Cost Section 3 Modification VI

ITEM	Modification VI with Scheme "A" & "B"	Modification VI with Scheme "C"
Depressed Roadway	5,875,000	9,840,000
Tunnel	12,211,000	14,286,000
Embankment Roadway	–	–
Cross Road Structures	77,000	218,000
Railroad Structures	–	–
Access Ramps	–	–
Frontage Roads	144,000	144,000
Utilities	915,000	724,000
Major Hydraulic Structures	1,333,000	1,481,000
Roadway Drainage	320,000	320,000
Lighting	270,000	95,000
Misc. – Signs, Signals, Landscaping Guard Rails Traffic Contr. Etc	2,441,000	985,000
Contingencies & Engineering	2,359,000	1,809,000
Total Construction	25,945,000	19,902,000
Demolition Cost	15,000	15,000
TOTAL	25,960,000	19,917,000

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CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 12 OF
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SUBJECT COST SECTION 3 MODIFICATION VII

ITEM	Modification VII with Schemes "A" & "B"	Modification VII with Scheme "C"		
DEPRESSED ROADWAY	5,875,000	9,840,000		
TUNNEL	12,211,000	4,286,000		
EMBANKMENT ROADWAY	—	—		
CROSS ROAD STRUCTURES	218,000	359,000		
RAILROAD STRUCTURES	—	—		
ACCESS RAMPS	—	—		
FRONTAGE ROADS	170,000	170,000		
UTILITIES	924,000	733,000		
MAJOR HYDRAULIC STRUCTURES	1,333,000	1,481,000		
ROADWAY DRAINAGE	320,000	320,000		
LIGHTING	270,000	95,000		
MISC.—SIGNS, SIGNALS, LANDSCAPING GUARD RAILS TRAFFIC CONTR. ETC	2,441,000	985,000		
CONTINGENCIES & ENGINEERING	2,376,000	1,827,000		
TOTAL CONSTRUCTION	26,138,000	20,096,000		
DEMOLITION COST	15,000	15,000		
TOTAL	26,153,000	20,111,000		

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ENGINEERS

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SUBJECT Cost Section 4 As Presented

Cost Section 4

Item	Schemes "A" & "B"	Scheme "C"
Depressed Roadway	8,697,000	7,392,0
Elevated Roadway	—	—
Embankment Roadway	—	—
Cross Road Structures	3,438,000	3,438,000
Railroad Structures	323,000	323,000
Access Ramps	979,000	979,000
Frontage Roads	970,000	970,000
Utilities	720,000	655,000
Major Hydraulic Structures	2,266,000	2,191,000
Roadway Drainage	240,000	240,000
Lighting	214,000	109,000
Misc.—Signs, Signals, Landscaping Guard Rails Traffic Contr. Etc	383,000	182,000
Contingencies & Engineering	1,823,000	1,648,000
Total Construction	20,053,000	18,127,000
Demolition Cost	78,000	78,000
Total	20,131,000	18,205,000

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CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 14 OF
DATE 4/22/65
LOCATION

UBJECT COST SECTION 4 Modification I

ITEM	Modification I with Schemes "A" & "B"	Modification I with Scheme "C"
DEPRESSED ROADWAY	8,623,000	7,442,000
ELEVATED ROADWAY	–	–
EMBANKMENT ROADWAY	–	–
CROSS ROAD STRUCTURES	3,089,000	3,113,000
RAILROAD STRUCTURES	323,000	323,000
ACCESS RAMPS	963,000	963,000
FRONTAGE ROADS	973,000	973,000
UTILITIES	699,000	641,000
MAJOR HYDRAULIC STRUCTURES	2,266,000	2,191,000
ROADWAY DRAINAGE	240,000	240,000
LIGHTING	214,000	109,000
MISC. – SIGNS, SIGNALS, LANDSCAPING GUARD RAILS TRAFFIC CONTR. ETC	416,000	215,000
CONTINGENCIES & ENGINEERING	1,781,000	1,621,000
TOTAL CONSTRUCTION	19,587,000	17,831,000
DEMOLITION COST	76,000	76,000
TOTAL	19,663,000	17,907,000

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CLARKESON ENGINEERING CO., INC.
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SHEET 15 OF
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SUBJECT Cost Section 4 Modification II

ITEM		Modification II with Schemes A & B		Modification II with Scheme "C"
Depressed Roadway		8,623,000		7,442,000
Elevated Roadway		—		—
Embankment Roadway		—		—
Cross Road Structures		3,089,000		3,113,000
Railroad Structures		323,000		323,000
Access Ramps		1,587,000		1,587,000
Frontage Roads		973,000		973,000
Utilities		730,000		672,000
Major Hydraulic Structures		2,266,000		2,191,000
Roadway Drainage		240,000		240,000
Lighting		214,000		109,000
Misc.—Signs, Signals, Landscaping, Guard Rails, Traffic Contr. Etc		416,000		215,000
Contingencies & Engineering		1,846,000		1,687,000
Total Construction		20,307,000		18,552,000
Demolition Cost		76,000		76,000
TOTAL		20,383,000		18,628,000

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CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 16 OF
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SUBJECT Cost Section 4 Modification VI

ITEM		Modification III with Schemes "A" & "B"		Modification III with Scheme "C"
Depressed Roadway		5,862,000		5,333,000
Tunnel		2,938,000		2,938,000
Embankment Roadway		—		—
Cross Road Structures		3,092,000		3,092,000
Railroad Structures		323,000		323,000
Access Ramps		1,740,000		1,740,000
Frontage Roads		977,000		977,000
Utilities		747,000		720,000
Major Hydraulic Structures		2,256,000		2,181,000
Roadway Drainage		240,000		240,000
Lighting		183,000		174,000
Misc.—Signs, Signals, Landscaping, Guard Rails, Traffic Contr. Etc.		457,000		510,000
Contingencies & Engineering		1,882,000		1,823,000
Total Construction		20,697,000		20,051,000
Demolition Cost		78,000		78,000
TOTAL		20,775,000		20,129,000

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CLARKESON ENGINEERING CO., INC.
ENGINEERS

SHEET 12 OF
DATE 4/26/65
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SUBJECT Cost Sections 1, 2, 3 Modification XIII (Scheme "C")

ITEM	Modif. XIII with Cost Section 1	Modif. XIII with Cost Section 2	Modif. XIII with Cost Section 3
Depressed Roadway	17,744,000	13,777,000	13,073,000
Elevated Roadway	–	–	–
Embankment Roadway	–	164,000	–
Cross Road Structures	1,229,000	1,834,000	1,036,000
Railroad Structures	–	2,087,000	–
Access Ramps	605,000	26,000	–
Frontage Roads	284,000	108,000	108,000
Utilities	993,000	900,000	711,000
Major Hydraulic Structures	1,073,000	1,859,000	1,484,000
Roadway Drainage	465,000	190,000	320,000
Lighting	150,000	100,000	41,000
Misc.–Signs, Signals, Landscaping, Guard Rails, Traffic Contr. Etc	150,000	181,000	512,000
Contingencies & Engineering	2,269,000	2,122,000	1,729,000
Total Construction	24,962,000	23,345,000	19,014,000
Demolition Cost	272,000	198,000	25,000
TOTAL	25,234,000	23,543,000	19,039,000

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CLARKESON ENGINEERING CO INC
ENGINEERS

SUBJECT Cost Section 5

SECTION 5 ITEM	Cost Section 5 As presented		Cost Section 5 Modif. XIV	
DEPRESSED ROADWAY	—		—	
ELEVATED ROADWAY	—		—	
EMBANKMENT ROADWAY	1,187,000		1,187,000	
CROSS ROAD STRUCTURES	392,000		392,000	
RAILROAD STRUCTURES	1,246,000		1,246,000	
ACCESS RAMPS	436,000		89,000	
FRONTAGE ROADS	501,000		501,000	
UTILITIES	188,000		171,000	
MAJOR HYDRAULIC STRUCTURES	209,000		209,000	
ROADWAY DRAINAGE	65,000		65,000	
LIGHTING	155,000		155,000	
MISC.-SIGNS, SIGNALS, LANDSCAPING GUARD RAILS TRAFFIC CONTR. ETC	185,000		185,000	
CONTINGENCIES & ENGINEERING	456,000		420,000	
TOTAL CONSTRUCTION	5,020,000		4,620,000	
DEMOLITION COST	245,000		245,000	
TOTAL	5,265,000		4,865,000	

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